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REGULATION AND SYSTEM INTERDEPENDENCE: EFFECTS ON THE SITING OF CALIFORNIA ELECTRICAL ENERGY FACILITIES

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(Ph.D. Thesis)

November 1980

ENERGY
AND ENVIRONMENT
DIVISION

Prepared for the U.S. Department of Energy under Contract DE-AC03-76SF00098

LBL-11531

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This work was supported by the U.S. Department of Energy, Assistant Secretary for the Environment, Office of Technology Impacts, Regional Assessment Division under Contract No. DE-AC03-76SF00098.

October 1983

PREFACE FOR THE PRINTING OF THIS DOCUMENT

The research for this project was conducted in 1979 and due to extenuating circumstances is only now being printed. Consequently, caution should be exercised in the interpretation of this material which is now to some extent outdated and limited in original scope. The members of the Energy Analysis Program of the Lawrence Berkeley Laboratory of the University of California are not responsible for the accuracy of the data or the interpretations; the author assumes this responsibility.

Any questions or comments about this research are most welcome and inquiries may be addressed to the author:

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Jaime Claire Kooser

Abstract

This study focuses on two aspects of the siting process for California electrical energy facilities: regulation of the siting process by the California State Energy Commission and the role of increasing system interdependence on the siting process. This study includes a review of public facility location theory and an evaluation of its contribution to the study of the electrical facility location problem. System interdependence, which refers to the physical and institutional arrangements of the utilities that demonstrate their interconnectedness, is specifically studied by examining the development and use of power pooling within the state to manage the supply of electricity. The examination of power pooling allows conclusions to be drawn about the effects of system interdependence on the siting process for new electrical energy facilities.

ACKNOWLEDGMENTS

This research has been generously supported by the Energy Analysis Program of the Lawrence Berkeley Laboratory of the University of California under the able direction of William E. Siri. This program is funded under the Department of Energy Contract No. W-7405-ENG-48. I wish to thank all the members of the EAP for their help and support over my years of association with them, especially Richard Sextro, Jayant Sathaye, Edward Kahn and Denise Boudreau. I owe a special debt to Ron Ritschard for being a kindred spirit and most of all to Nancy Schorn for her unfailing support and friendship.

I also wish to thank the individuals of the Pacific Gas and Electric Company who not only consented to be interviewed but gave generously of their time. Their discussions provided me with critical information for my analysis.

My friends and colleagues, each in a special way, have given me encouragement through a difficult time. I wish to thank Roger Miller, who read several chapters of my dissertation, Susan Christopherson, who understands the spring quarter of 1980 and especially Mary Sue Moore, whose understanding and support have been invaluable. I am most grateful to Arlene Banoul, who remained close despite distance, and to Mary Adamson, my true companion throughout, for friendships unsurpassed. I am indebted to Michael Teitz for taking me on as his student in spite of his busy schedule and for his stimulating conversations. It is impossible to adequately express my gratitude to Allan Pred, a most incredible human being. He truly appreciates what this work represents and I thank him for his patience, guidance, and his friendship.

Finally, I wish to thank my family whose love for me, expressed in many ways, has been a source of strength.

DEDICATION

I dedicate this work with love to Louise Lechner Kooser

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CHAPTER ONE: INTRODUCTION

Energy, which we have wielded in vast quantities and sophisticated forms for decades, is inextricably woven into our way of life. Yet changes in the supply of crude energy forms have forced us to question our previously unchecked use of energy. The energy crisis of 1973-1974, which emphasized the frail connections between foreign energy suppliers and United States energy consumers, was particularly important in this respect. Clearly our values will be reexamined and gradually modified as we grapple with the complex problems of the energy industry. In the United States and other highly industrialized countries, the energy industry is multifaceted, with both the private and public sectors pursuing the exploration and extraction of fossil fuels (coal, oil and natural gas), the conversion of these new energy materials into usable forms (such as gasoline and petrochemical feedstocks) and the integration of energy into the economy. In the highly centralized energy supply system of today, a key role is played by the electrical utilities, which convert raw energy materials into electricity, one of the highest quality forms of energy.[1] Electricity, generated from fossil fuel, nuclear, geothermal and hydroelectric power plants, is distributed to industrial, commercial and residential users over an incredibly complex distribution grid of transmission lines, substations and local low voltage lines. It is to the provision of this form of energy through the government regulated private and public utilities to which we direct our attention.

While different aspects of electricity production and distribution are of importance for geographers, clearly the process through which these organizations make their decisions about the provision of electricity are of concern to the economic geographer, for ultimately these decisions have a great impact not only on the visible landscape in which the power plants themselves are located, but also on the location of the commercial, residential and industrial users of electricity. In addition to the locations of the electrical users, the decision-making process becomes more important in light of the serious environmental consequences of continued high levels of energy production and use and because government intervention in the decision process for siting electrical generating and transmission facilities has increased.

Since the National Environmental Policy Act of 1969, the siting process for power plants, transmission lines and other energy facilities has become more constrained while simultaneously becoming more public and more visible than before. Previously, concern was not voiced to any serious degree by any group. In fact, the individual utility had a rather free reign on deciding where and when to build power plants. Certainly the question of need was never seriously raised, for it seemed obvious that the post World War II United States required ever increasing amounts of electricity to maintain and improve the standard of living, to sustain the rate of growth in the Gross National Product (GNP) Index and to support the general upswing in the economy following the war. It was in this period that most of the electrical utilities experienced their most rapid rate of growth. For example, the Pacific Gas and Electric Company (PG&E) added eleven new plants, with a total of 1.4 MW, between 1945 and 1951.[1A] The utilities acted primarily in their own interests, and sought to add to their baseline capacity[2] as rapidly as possible, without much regard to the impacts this had on the physical and social environment. The increasing concern in the 1960's over the quality of the physical environment which prompted the National Environmental Policy Act (NEPA) of 1969, swept up the electrical utilities as well. The isolation in which the utilities operated in the 1950's was replaced in the 1960's and 1970's by an emphasis on greater regulation by governmental agencies, greater emphasis on public participation in the decision-making process and more concern with the range of impacts resulting from the construction and operation of an energy facility. In addition to the changes wrought by NEPA and the California Environmental Quality Act (CEQA) of 1970, a major shift in regulation of the siting process occurred with the introduction of the California Energy Commission (CEC) in 1975. Thus we can point to the importance of the present decision-making process of the California electrical utilities which departs significantly from the process which existed in the 1950's.

This study will focus on two aspects of the decision-making process of the California electrical utilities, namely, the regulation of the siting process and the role of increasing system interdependence in the siting process. Theoretically, the electrical utility location or siting decision may be classed as a public facility location theory problem, because electricity, regardless of the ownership of the facilities, is public in the sense that it is a government regulated monopoly. Thus, the first step in this study is a review and evaluation of the present body of applicable location theory to determine the theoretical basis we have for understanding the siting process (Chapter Two). This will include a discussion of "public" versus "private" utilities and the significance of ownership in the siting process. Secondly, we must describe the decision-making environment of the California electrical utilities, especially their relationship with regulatory agencies, because the analysis of the siting process cannot be understood if it is divorced from the context in which it takes place (Chapter Three). This will include a description of the siting process as outlined in the Warren-Alquist Act. Although this will give us the general legal framework which guides the siting decision-making process, we must narrow our consideration of this process to a specific aspect, namely the role of system interdependence, in order to analyze the general trends in energy facility siting (Chapter Four). System interdependence refers to both the physical and institutional arrangements of the utilities that demonstrate their interconnectedness. While some connections between the utilities have existed for many decades, within the last fifteen years these linkages have proliferated. Power pooling as an effective way to manage reserve margins and planned additions to capacity has been employed since the second World War[3] but it now plays an especially important role in California electricity supply. The Western Systems Coordinating Council (WSCC), a reliability council, and the California Power Pool Agreement of 1964 represent formal institutional arrangements that indicate the trend to interconnectedness. In addition, practices such as "banking"[4] and energy exchanges[5] are short term contractual agreements whose success lies in the coordination of the utilities and of shared physical equipment, primarily connected and compatible transmission lines. Documenting these developments will be instructive, but more importantly, we can see how the siting process as directed by the primary regulatory agency, the California Energy Resources Conservation and Development Commission, or simply the California Energy Commision, affects this system interdependence. Ultimately, we may expect that the pattern of energy facility sites visible on the landscape will reflect the role of system interdependence in the siting process.

What are the problems to be specifically addressed? There are two: first, what does public facility location theory contribute to the study of the provision of electricity; and secondly, how do regulation and system interdependence affect the siting process? Prima facie, it seems that in the short run that system interdependence makes it easier for the utilities to meet their demand, while in the long run it seems to hinder their efforts at siting more power plants because of the regulatory policies of the CEC which are directed to developing a sound statewide system. Chapter Four will address this question.

The analysis of a process as complicated as the power plant siting process requires a comprehensive framework. The time-geographic framework developed by Torsten Hagerstrand, Allan Pred and others[6] has proved in many research applications[7] to be such a comprehensive framework. For this particular study, it would have been instructive to use the project concept of time-geography to structure the conceptualization of the dissertation problem. Unfortunately, due to time and financial limitations, it was not possible to undertake the type of detailed data gathering that a full application of the time-geographic approach would necessitate. This does not, however, preclude a thoughtful consideration of how such a study would be formulated and speculation on the insights to be gained from the time-geographic assessment. This topic will be considered in Chapter Five, Conclusions and Suggestions for Further Research.

In this research, data such as specific regulations and information on proposed electrical generating facilities, were gathered from the standard published data sources of government agencies as well as from the electrical utilities. It was necessary to supplement this data because the type of information needed for the analysis (for example, in attempting to understand system interdependence) were not conveniently available. Thus, in-depth interviews were carried out with key people in the CEC, the California Public Utilities Commission (CPUC) and other regulatory agencies and in the PG&E, which is the California electrical utility that will serve as the case study. (The selection of the case study electrical utility is discussed more fully in Chapter Four.) In addition, much of the analysis will rest on an assessment of the relevant literature. In fact, a major contribution of this work will be the interpretation and evaluation from a geographic viewpoint of the scattered and broad literature that bears on the siting process.

The remainder of this chapter has two parts which provide a backdrop for the succeeding chapters. First, we will depict the trends in energy use in general, and electricity use in particular for California over the last several decades. This illustrates the scale and importance of the siting problem as well as the magnitude of the demand for electricity. Secondly, we will briefly discuss the nature and extent of the contribution that geographers have made to the study of energy.

Energy Use in California

The California energy industry has four major sectors: 1) oil and gas extraction; 2) petroleum refining and related industries; 3) electric utilities; and 4) gas utilities.[8] Data for crude oil production, natural gas and natural gas liquids production is shown in Figure 1-1. This data shows that between 1964 and 1968, petroleum production grew at an annual rate of 5.6 percent. However, from 1969-1975, the production of petroleum declined about 3.0 percent per year. Natural gas production averaged 683 billion cubic feet per year from 1964 through 1968. Then production went into a steady decline of 9.4 percent per year from 1968-1975. The production of natural gas liquids was steady from 1964 to 1967, but then it gradually decreased. The average annual rate of decline from 1964-1975 was 8.5 percent for natural gas liquids. In 1975, the crude oil production in California represented 10.6 percent of the national total production and production for natural gas and natural gas liquids together represented less than 2 percent of the national total. This clearly demonstrates that primary energy production is declining in California, forcing the state to rely increasingly on out-of-state and foreign sources of fuel. In fact, in 1970 California imported 10 percent of its oil supply, but by 1977 this had risen to 41 percent.[9] The state has not been able to rely solely on in-state production of natural gas and oil since the late 1940's.[10] The two major reasons for this are the shift to gas and oil-fired steam turbine electricity generating units and the greatly increased consumption of gasoline in automobiles. In 1960, the per capita consumption of gasoline was 340 gallons per year, which increased 60 percent by 1977 to 533 gallons per year.[11] Presently per capita consumption of gasoline is decreasing. The consumption of natural gas by end-use sector is tabulated for 1960, 1965, 1970 and 1975 in Table 1-1 and is illustrated along with the consumption of oil and electricity in Figure 1-2.

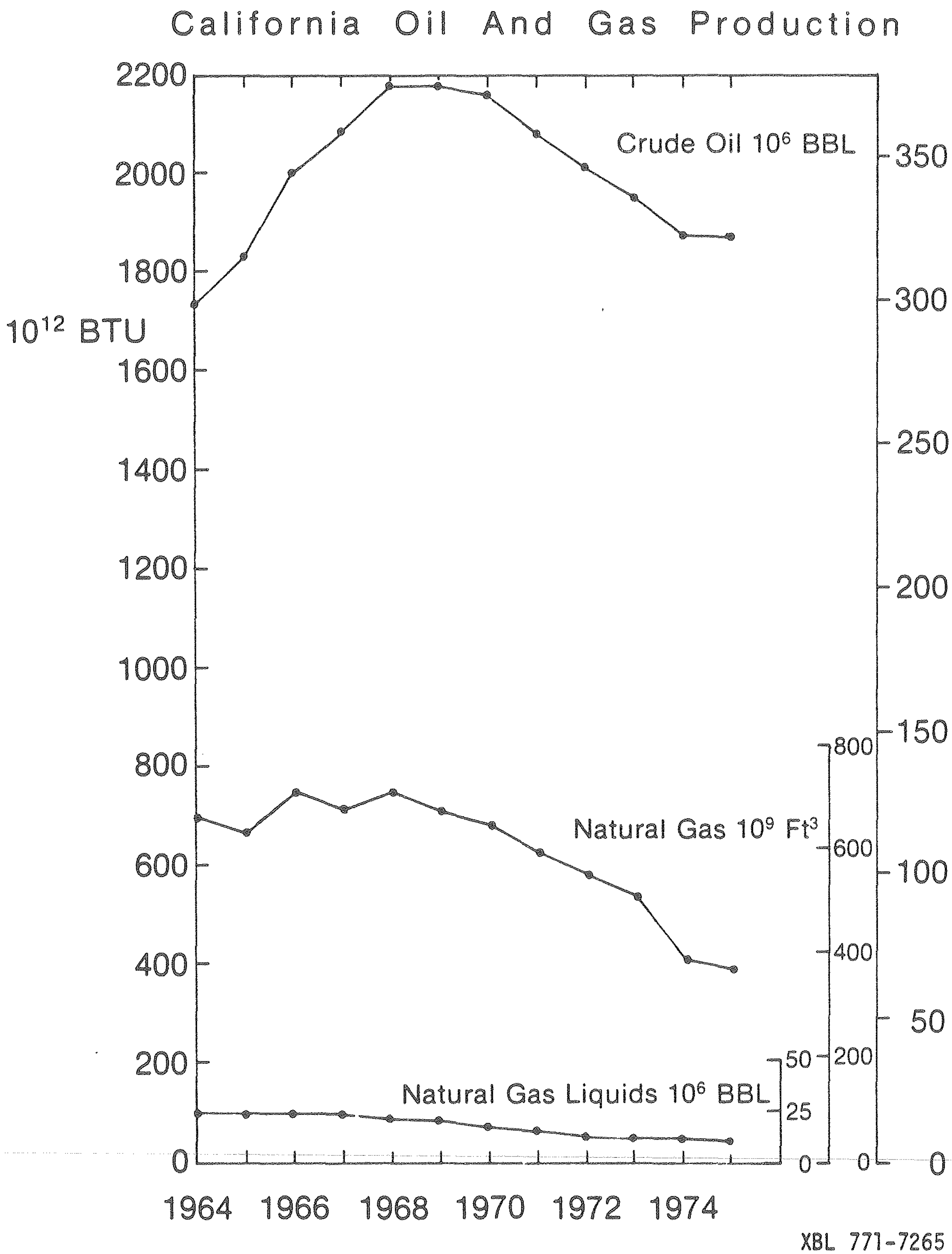

California Oil And Gas Production
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
10^12 BTU
Crude Oil 10^6 BBL
Natural Gas 10^9 Ft^3
Natural Gas Liquids 10^6 BBL
350
300
250
200
150
100
50
0
800
600
400
200
0
50
25
0
1964
1966
1968
1970
1972
1974
XBL 771-7265

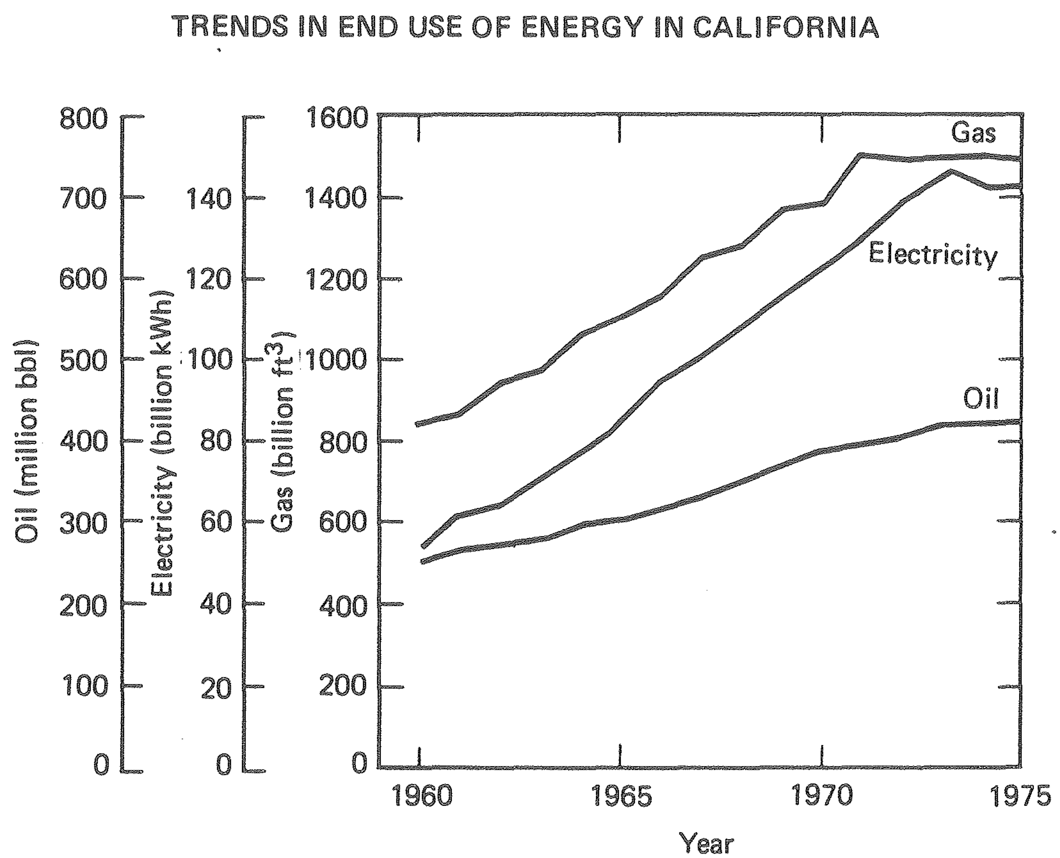
Fig. 1-1

Table 1-1

Use of Energy by Sector in California

Sector	Energy Use (trillion Btu)			
	1960	1965	1970	1975
Residential				
Natural gas	394	526	594	566
Electricity	58	79	418	154
Total, end use	452	605	712	720
Total, primary	572	769	957	1040
Commercial				
Natural gas	117	176	226	243
Electricity	48	103	165	177
Total, end use	165	279	391	420
Total, primary	265	493	734	788
Industrial				
Natural gas	342	412	615	686
Electricity	76	101	133	140
Petroleum	349	380	484	367
Total, end use	767	893	1232	1193
Total, primary	925	1103	1508	1484
Transportation				
Gasoline	752	934	1153	1362
Other	340	118	571	733
Total, end use	1092	1352	1724	2095
Total, primary	1092	1352	1724	2095
Totals				
End use	2476	3129	4059	4428
Primary	2854	3717	4923	5407

Source: Ahern, William, et al., Energy Alternatives for California: Paths to The Future, Santa Monica, California, Rand Corporation, 1975.



Source: Ahern, William, *et. al.*, *Energy Alternatives for California: Paths to the Future*, Santa Monica, Rand Corporation, 1975

XBL809-1945

Fig. 1-2

Coal has not been a major source of energy for California. No coal is presently used to generate electricity in the state, although California imports coal-generated electricity from the southwestern states (see Figure 1-6). The Pacific Gas and Electric Company (PG&E), however, has proposed two 800 megawatt coal-fired power plants for a northern California location (Solano County and Butte County sites were approved in the Notice of Intention process, August 1, 1979) and Southern California Edison has proposed a 100 MW integrated coal gasification/ combined cycle demonstration plant for San Bernardino County and two 500 megawatt units for a southern California location.

A comparison of California energy consumpion in 1960 with consumption in 1977 reveals several interesting patterns (Table 1-2). The first major shift is the addition of nuclear and geothermal resources for electricity production. The use of natural gas for electricity generation decreased by six percent, while that of oil showed a major jump of ten percent.

This documents the trend already mentioned of a shift to oil-fired steam turbine power plants. A four percent increase in the use of petroleum from 1960 to 1977 can be seen, as well as a drop in non-residential use of petroleum and approximately the same portion of petroleum going to transportation. Finally, we can note that the proportions of energy consumption among the three major end-use categories (residential, non-residential and transportation) has remained roughly the same (16 percent and 15 percent, 44 percent and 43 percent, and 40 percent and 42 percent for 1960 and 1977 respectively). A diagrammatic flow of the 6298 trillion Btu consumed in 1977 is shown in Figure 1-3.

Table 1-2

Energy Consumption Patterns: 1960 and 1977

Energy Source	Percentage of Supply	Percentage of Energy Sources Going to Specific End Uses
1960		
Hydroelectricity	2%	100% electricity generation
Coal	1%	100% non-residential (industrial)
Natural Gas	37%	28% electricity generation 32% residential use 40% non-residential
Petroleum	60%	8% electricity generation 1% residential 33% non-residential 58% transportation
1977		
Hydroelectricity Nuclear Geothermal	5%	100% Electricity
Coal	3%	28% non-residential 72% electricity generation
Natural Gas	28%	22% electricity generation 34% residential 44% non-residential
Petroleum	64%	18% electricity generation 3% residential 26% non-residential 56% transportation

Source: California Energy Commission, Energy Choices for California ... Looking Ahead, 1979.

1977 CALIFORNIA ENERGY FLOW

Total Consumption
6298 Trillion Btu

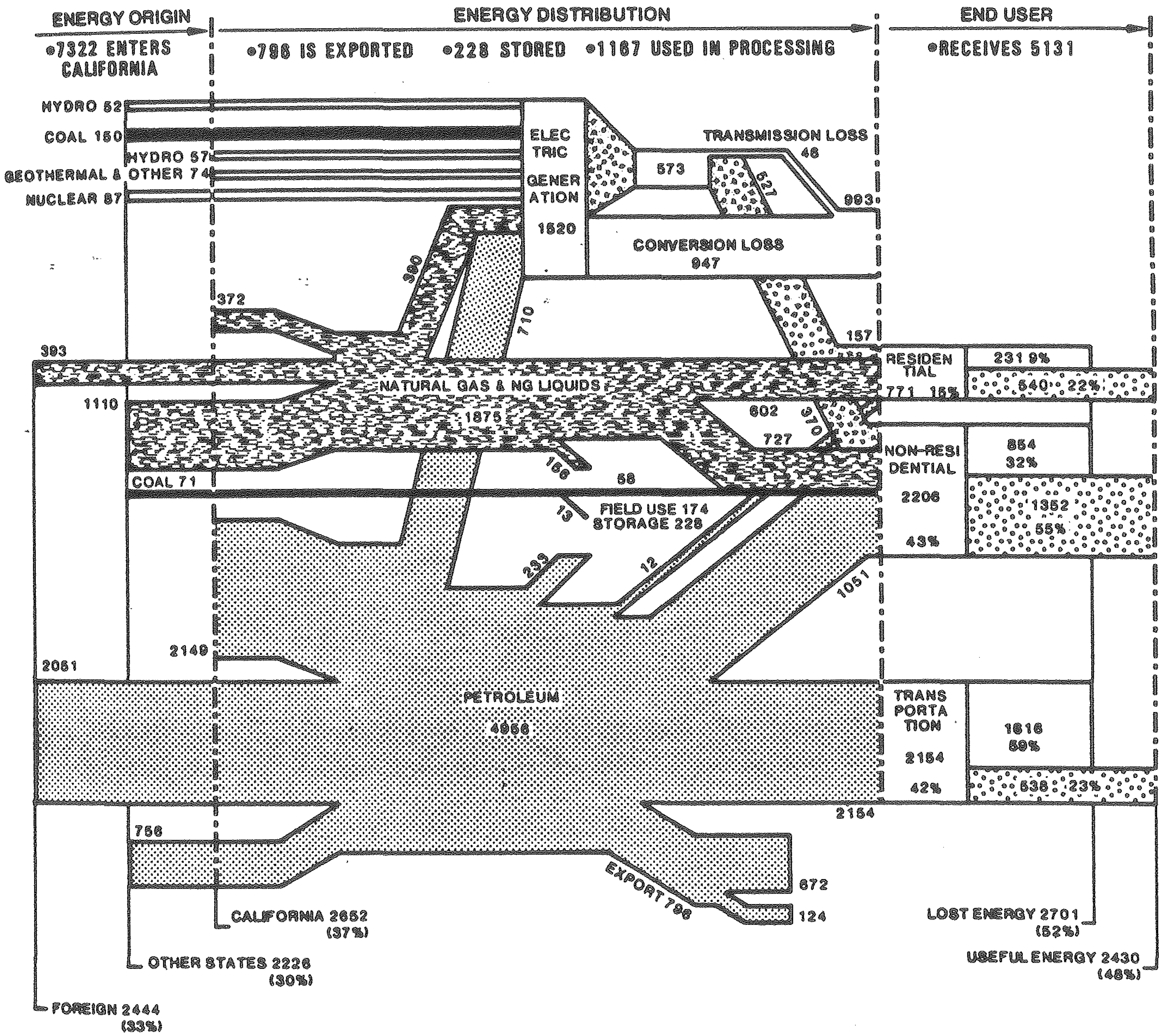
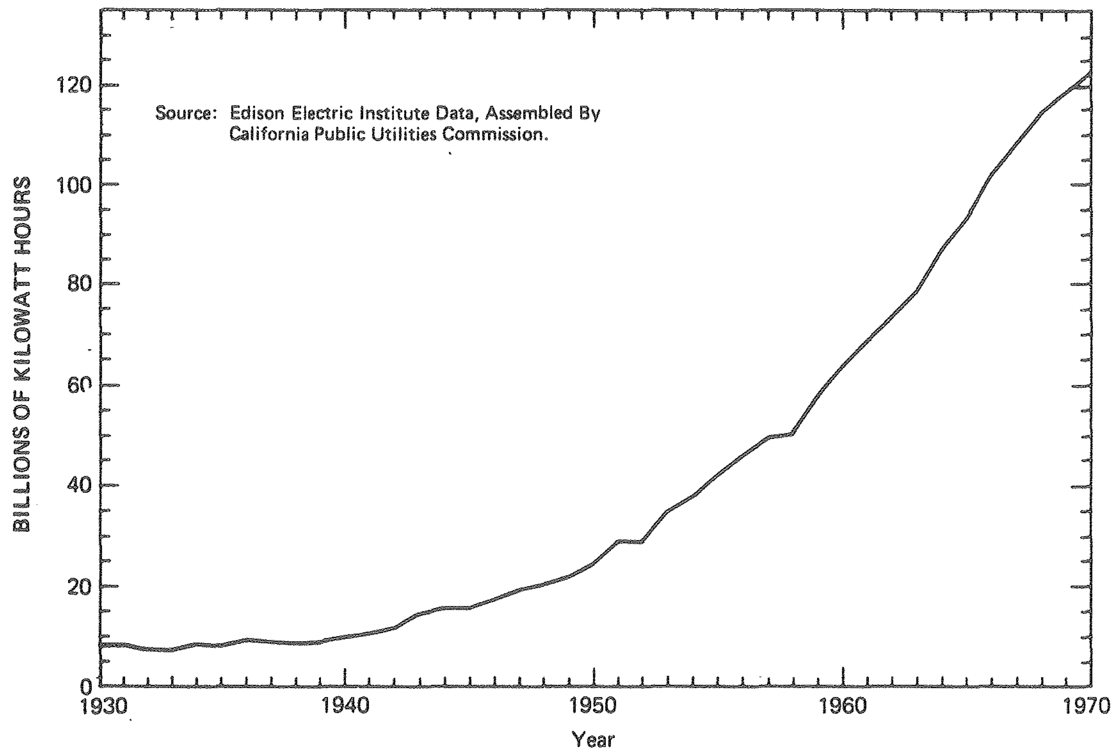


Fig. 1-3

Now that the general trends in overall energy consumption have been examined, we will consider the trends in electricity consumption more closely. Figure 1-4 dramatically illustrates the sharp increase in electricity consumed in the post World War II decades. By 1973, Californians were consuming more electicity in one month than had been consumed in the entire year of 1930; in 1940, 10 billion kilowatt hours were generated, and by 1970 this had risen to 122 billion kilowatt hours of electricity.[13] In addition to the tremendous growth in electricity sold, maximum demand or peak demand[14] also rose steeply from 1940 to 1970 (Figure 1-5). The CEC states that from 1963 through 1973, peak demand grew at an annual rate of 6.8 percent, while total electricity sales increased by 6.6 percent. The oil embargo of 1973-1974 slowed the growth rate considerably, dropping to 4.5 percent and 3.2 percent respectively.[15] Overall, the steady growth in the use of electricity in the 1960's continued into the early 1970's, but dropped sharply after the oil embargo. Although the rate at which it continues to expand is reduced, the general trend has neverthelsss been to an increased dependence on electricity as a source of energy.

What are the fuels used to produce the electricity? Figure 1-6 illustrates the absolute amounts of electricity generated from hydroelectric, natural gas, fuel oil, geothermal, nuclear, and coal sources. In Figure 1-2 we have already presented the percentage contribution made by each fuel type. The important changes have been the introduction of nuclear and geothermal energy sources, the shift to oil-fired capacity, the precipitous decline in natural gas as a fuel for electricity generation (in 1960, natural gas provided 61 percent of electricity,

ELECTRICITY SOLD IN CALIFORNIA, 1930-1970

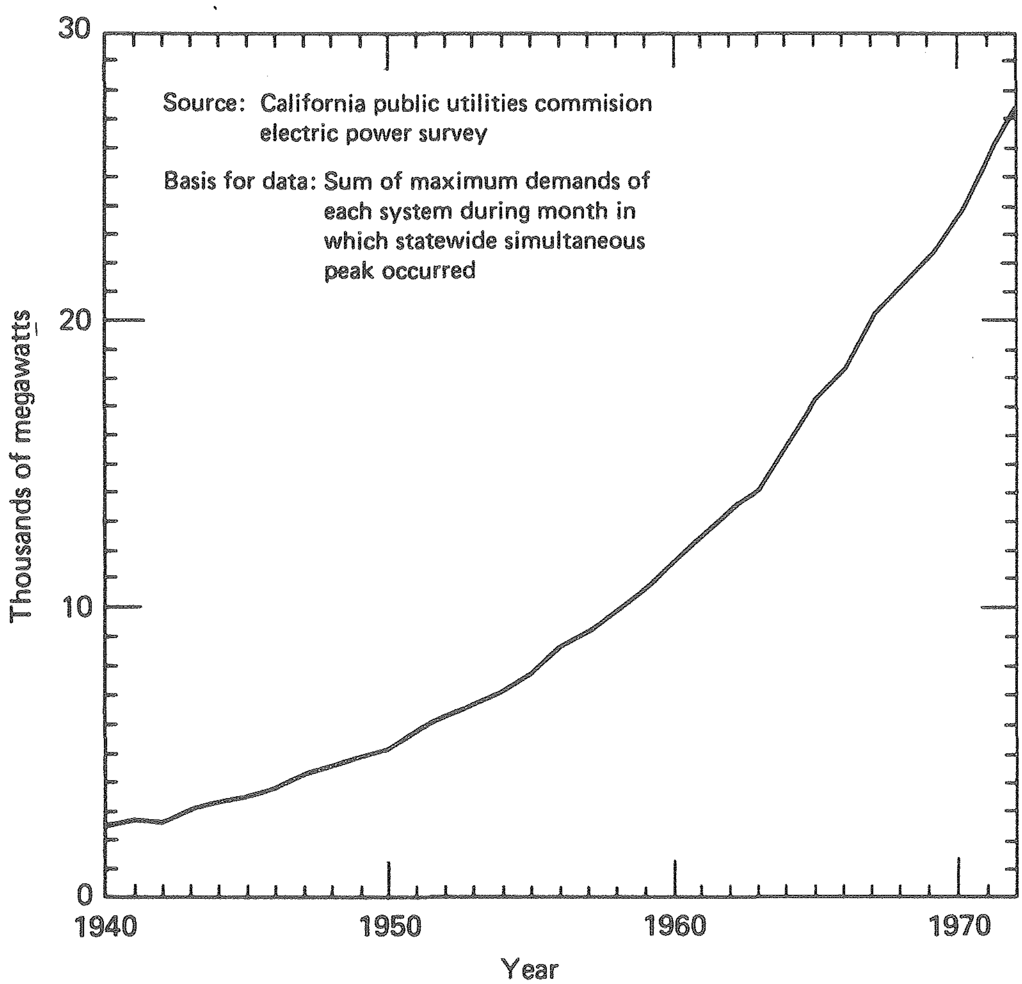


Source: Livermore, Norman B., Jr., *Energy Dilemma: California's 20-Year Power Plant Siting Plan*, State of California, Resources Agency, 1973

XBL 809-1943

Fig. 1-4

MAXIMUM DEMAND IN CALIFORNIA, 1940-1972

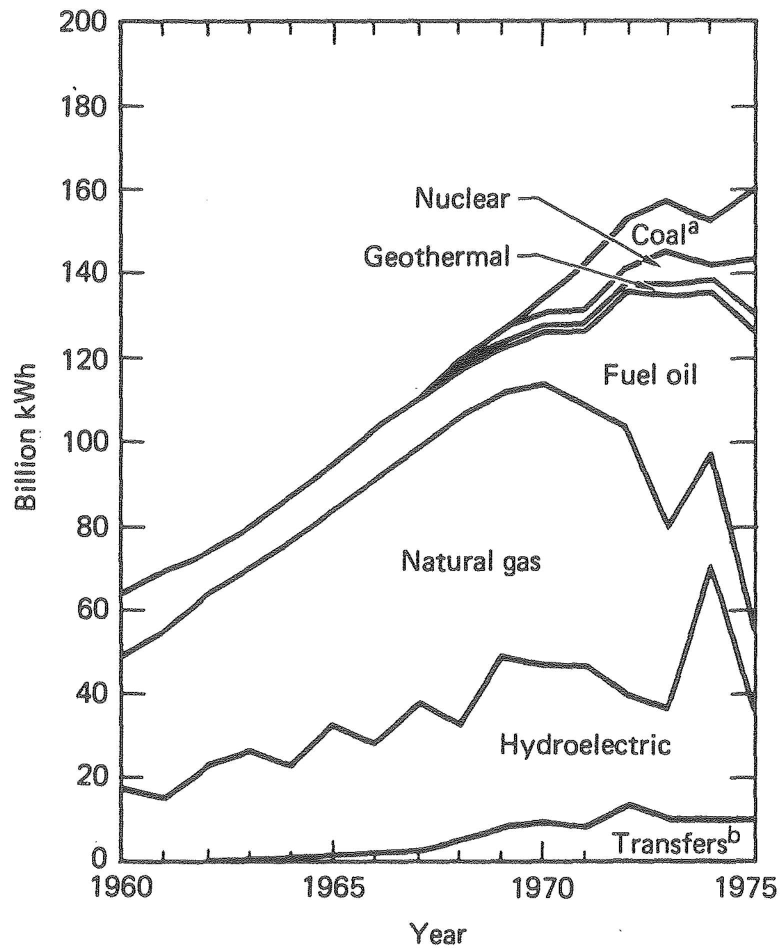


Source: Livermore, Norman B., Jr., *Energy Dilemma: California's 20-Year Power Plant Siting Plan*, State of California, Resources Agency, 1973

XBL 809-1941

Fig. 1-5

ELECTRICITY PRODUCED FOR USE IN CALIFORNIA
BY SOURCE OF ENERGY



Notes: a) Coal indicates out of state coal generated electricity

b) Transfers indicates other out of state supplies, primiarily from the Bonneville Power Administration

Source: Ahern, William, *et. al.*, *Energy Alternatives for California: Paths to the Future,* Santa Monica, Rand Corporation, 1975

XBL809-1942

Fig. 1-6

but by 1977 this declined to 28 percent),[16] and the importation of electricity from out-of-state sources. (California presently imports 17 percent of its electricity,[17] of which 10 percent is coal-fired capacity.)[18] Important decisions about our future supplies of electricity are being made now; it is difficult, if not impossible, to forecast which fuels will be relied on over the next several decades.

In California there are five investor-owned electrical utilities, eight publicly-owned utilities, and eleven public agencies, all of which produce electricity which they consume and sell to other utilities. The spatial distribution of the electricity generating facilities in 1976, which totals 242 units, is shown in Map 1-1. The breakdown by type of plant is given in Table 1-3.

The pattern of location shows several distinct clusters. First, the hydroelectric plants are clustered in the Sierra Nevada mountain range in the eastern part of the state from Plumas County down to Tulare and Inyo Counties. In addition, there is another cluster in Shasta County. The geothermal plants are necessarily constrained to the region where the geothermal source exists; they are clustered in northeastern Sonoma County. The major concentration of fossil fuel energy facilities are in metropolitan areas, including the San Francisco Bay area, the Los Angeles area and the San Diego metropolitan area. Southern Imperial County has a cluster of small electricity-generating plants. Finally, the three sites with operating nuclear power plants are scattered throughout the state, with one each in Humboldt County, Sacramento County and San Diego County. A fourth site with nuclear units nearing completion is located on the coast in San Luis Obispo County.

CALIFORNIA ELECTRIC UTILITIES

EXISTING ELECTRICAL GENERATING PLANTS 1976

Source: CERCEC, California Energy Trends and Choices, vol. 7, Power Plant Siting

Map 1-1

Table 1-3

Type and Number of Existing
Electrical Generating Plants

Type	Number of Units	Total Installed Capacity (in megawatts)
Hydroelectric	172	8438
Nuclear	3	1534
Fossil Fuel	61	24201
Geothermal	6	561
TOTAL	242	34734

Source: California Energy Resources Conservation and Development Commission, California Energy Trends and Choices, Vol. 7, Power Plant Siting, 1977.

The present pattern of energy facility siting is not likely to continue for several reasons. First, the concentration of power plants in metropolitan areas is not likely to increase due to air quality problems and health and safety effects from the proximity to population concentrations. This is particularly true for nuclear power plants. Second, the number of potential sites for additional hydroelectric development has decreased as most of the usable sites have already been developed. The Department of Water Resources has estimated, however, that hydroelectric output could be expanded by approximately 30 percent, although the environmental impacts of doing so have yet to be considered. Third, the predominance of coastal siting is not likely to be reinforced due to the Coastal Commission policies designed to help conserve coastal resources. Thus a shift in the siting pattern of energy facilities is likely to occur over the next decade with the central portion of the state and the southeastern desert area receiving increased attention as power plant siting areas.

Any shift in the pattern of siting power plants has obvious ramifications for the expected pattern of transmission facilities, The present spatial distribution of transmission lines in California is illustrated in Map 1-2. This spatial distribution is a critical element in the siting process because the present pattern directly constrains and shapes any future pattern of growth. In order to maximize the benefit of utility of the capital investment, future additions to the system necessarily tie into the old. Many factors which play a role in the development of system interdependence are thus directly related to the transmission system. A clear depiction of this system growth can be seen in Map 1-3, which shows how the early links of the PG&E transmission system have been reinforced in later expansions.

California Transmission Line System

LEGEND

- Fuel
- Hydro
- Transmission Substations
- Distribution Substations

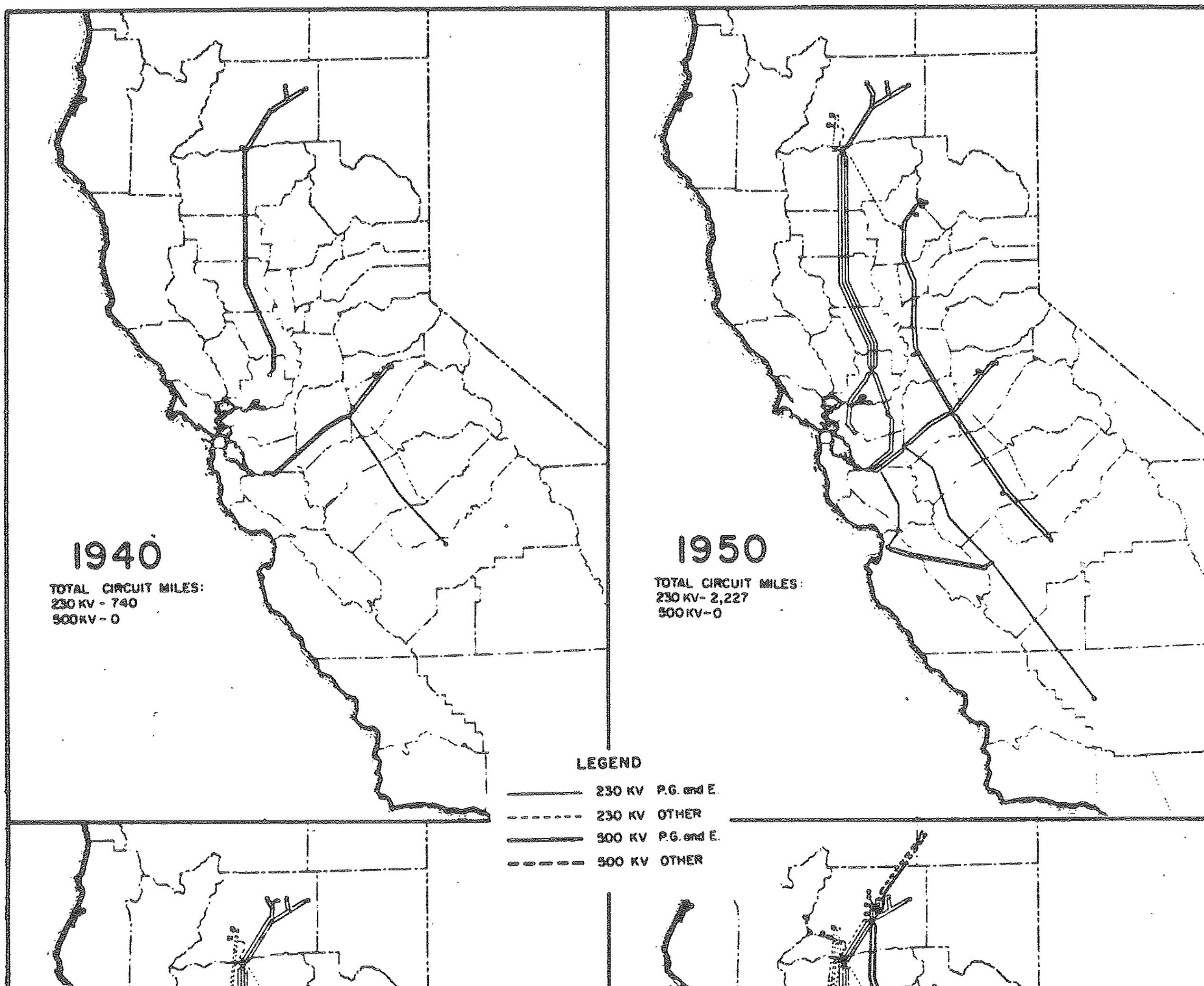
Transmission substations shown where there is a change in voltage only

All transmission lines shown are 189 kilovolts or greater

1″ = approx. 70 miles

CBB 777-6977A

Map 1-2



GROWTH OF 230-KV (and Higher) TRANSMISSION LINES
IN AREA SERVED BY PACIFIC GAS AND ELECTRIC COMPANY

Source: Pacific Gas and Electric Company

Map 1-3

We have described the trends in energy consumption in California, in particular those of electricity consumption as well as presenting the present day spatial distribution of power plants and transmission lines. This serves as a backdrop for the present study. We will now consider geographic research on energy.

Geography of Energy

In recent years, the rapidly changing energy economy of the United States has commanded the research attention of more and more geographers. The work is reflected in the sessions of the annual meetings of the Association of American Geographers (AAG), in recent Ph.D. dissertations,[19] in the research of applied geographers[20] and in several academic departments.[21] The 1977 annual meeting of the AAG in Salt Lake City, Utah provided a particularly rich sample of the current interests of geographers concerned with energy. Seven sessions were organized to accommodate the participants: "Fossil Fuels: Management and Policy Problems," "Nuclear and Fossil Energy Location and Distribution," "Assessment of the Solar Energy Resources of the West," "Energy Facility Siting: Environmental Impacts," "Energy Siting: Case Studies on Methodology," "Energy: Impact Assessment and Planning" and "Energy: Alternative Sources and Conservation." These sessions and the numerous energy sessions of other AAG meetings are ample evidence of the tremendous increase in research on all aspects of energy production and consumption.

A notable feature of this work is an emphasis on the policy-making aspects of energy studies, demonstrating a shift to applied geographic work. Thomas Wilbanks has outlined five areas of policy-oriented geographic research: 1) implications of the differing geographic distributions of energy resources and energy demand; 2) economic and social impact assessment; 3) energy facility siting; 4) determinants of energy-using spatial behavior; and 5) technology transfer.[22] Most of this work is sponsored by government agencies (especially the Department of Energy through the national laboratory system and individual contracts), and private organizations such as the Edison Electric Institute and the Ford Foundation. Thus the published results do not always appear in the academic literature, and it is impossible to provide a comprehensive review of the literature here. Nevertheless, the work of geographers outside of academia is becoming increasingly important. The emphasis on policy, practical application and social and institutional aspects of energy distinguish their efforts from the traditional economic geography approach which has been primarily descriptive of the spatial distribution of energy resources.

There are two main ways that energy has been studied academically. One portion of the literature has been preoccupied with evaluating the spatial distribution of energy resources so as to determine the potential for extraction. Another portion has considered energy as a factor in analyzing the locational pattern of industry. An examination of the last twenty years of Economic Geography supports this depiction of the literature. Some representative article titles are: "Oil in Libya, Some Implications,"[23] "Current Problems of the Soviet Electric Power Industry,"[24] "Changes in the Supply of Coking Coal in Belguim,"[25] "The Geography of the Nigerian Petroleum Industry,"[26] and "Optimal Transportation Patterns of Coal in the Great Lakes Region."[27] These articles are mainly descriptive, giving basic geographic information on the location of the energy resource, the industries and the power plants. The roles of transportation in linking the primary energy fuel with the power system or industry is often emphasized. An exception is the article on coal in the Great Lakes region, which instead models the present patterns of coal movements in order to formulate optimal routing patterns. In order to more carefully delineate this type of economic geography, we will examine two articles in detail. The work of Brown and Simonett is important because they are concerned with the growth of integration of an electrical supply system which is relevant to the present concern with system interdependence. Rodgers' work is a particularly good example of the traditional economic geographic concern with factors affecting industrial location.

Brown and Simonett, in their article entitled "Integration and Locational Change in the Australian Electricity Industry: 1951-1965,"[28] give a description of the spatial distribution of energy facilities in Australia and detail how extra-high voltage (EHV) transmission technology, in conjunction with changing economic conditions and demand, permitted the expansion and integration of the grid system. The questions which they consider geographically significant are these: "What is the nature of the power systems' development, the resources, and the technology that has given rise to the present patterns in the power industry? What will be the effect of the present pattern on future growth? Finally, what economic advantage, if any, do these new power developments bring to Australian industry?"[29] Before approaching these questions, the authors reviewed the fuel resources of the several Australian states, explaining in detail the distribtuion of coal, hydroelectric, oil, gas and fission fuel resources. The spatial distribution of the electrical generating facilities in 1951 showed a concentration of thermal coal-fired plants in the cities. Brown and Simonett contrast this pattern with the "power pattern" of 1963 which indicated that transmission line improvements had enabled smaller areas outside the major cities to integrate into the established urban system.[30] Due to three different types of load centers which had emerged by 1963, Brown and Simonett then break the discussion into three parts, considering the Southeast, Tasmania and the sparsely populated states in turn. They conclude with a discussion of the trend towards larger units and greater interconnection, the shift to natural gas as a fuel and the possibilities of employing nuclear power.

Brown and Simonett are principally concerned with answering the first question that was raised early in the article. Except for a brief discussion of industrial location in Tasmania, the second question is not addressed. The authors discuss the governmental policies of the Southeast and Tasmania, including a uniform bulk tariff, which encouraged rural electrification and thus the consolidation of the power grid in the Southeast.[31] While the evaluation of government policies is important to assessing the critical factors having influenced the development of the electricity system, some consideration of related industrial location policies is necessary. Furthermore, the discussion of government policies are not incorporated into an analysis of the future growth patterns. This article lacks a clear conclusion that summarizes how the information presented deals with the geographically significant questions. Finally, the article contains the implicit value judgment that the continued development of the electricity grid system is good or inevitable. The authors probably did not think that a critique of the values involved in such development was either necessary or appropriate. It is undoubtedly the hindsight of the intervening twelve years that makes this seem naive. One can only imagine the great amount of environmental destruction necessitated by the large-scale exploitation of the brown (low quality) coal resource ("...the overburden of about 40 feet is removed by a huge bucket-chain dredger capable of moving 1300 cubic yards of solid overburden an hour.")[32] A case can perhaps be made that these matters should have been weighed in speculating on the future growth patterns, for even if aesthetic concerns are set aside, this type of resource use would affect future population expansion. In conclusion, Brown and Simonett do a good job of tracing the development of the Australian electricity industry, but they only partially succeed in going beyond description to an analysis of the locational patterns.

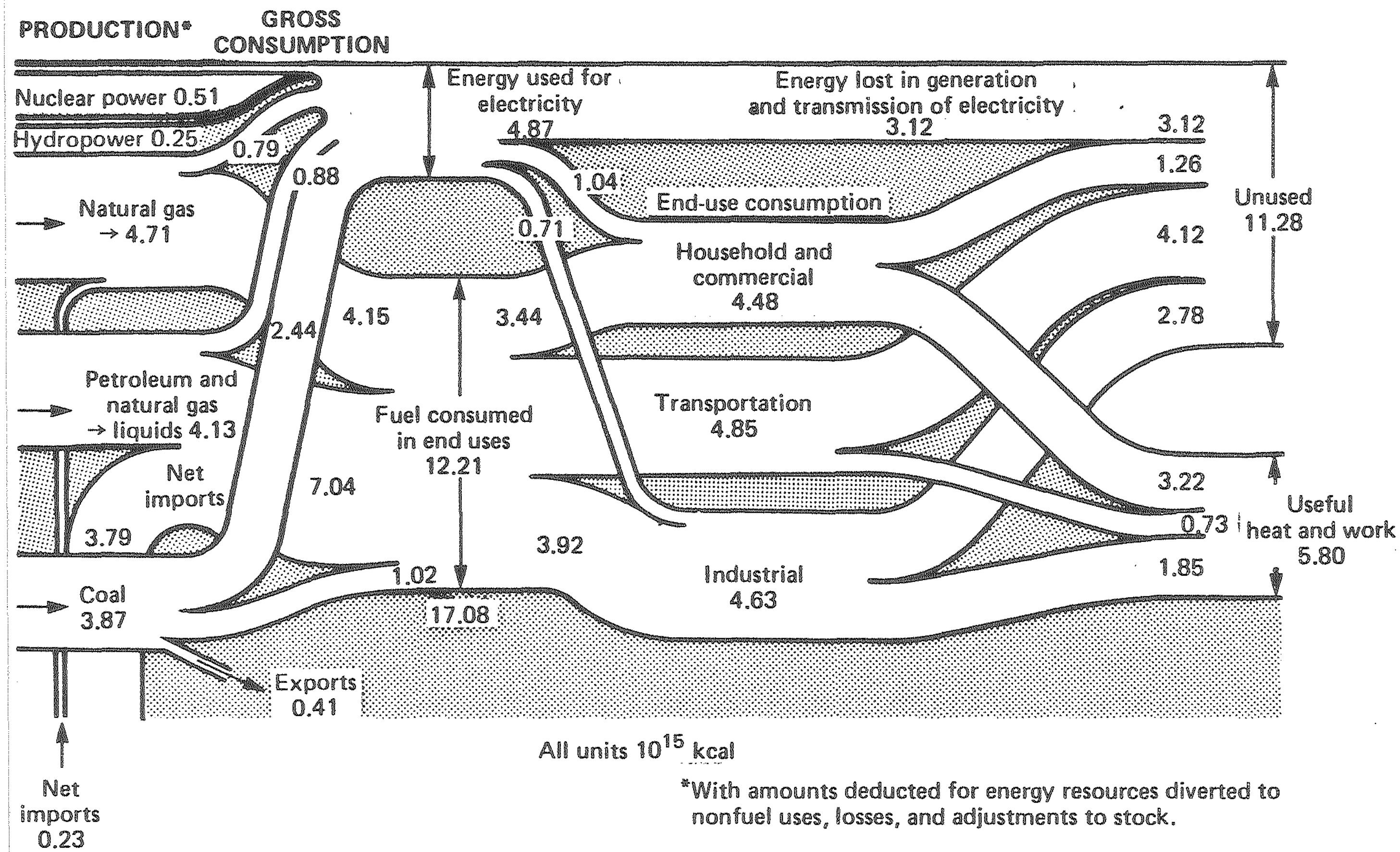
An article which exemplifies the economic geographer's concern with how a primary fuel source affects industrial location is "Coking Coal Supply: Its Role in the Expansion of the Soviet Steel Industry" by Allan Rodgers.[33] This thorough and exceptionally well written article details, basin by basin, the nature and extent of Soviet coking coal supplies. Rodgers provides a careful analysis of production figures, transportation costs and of how the properties of the coal determine the actual cost and usefulness of the coking coal. For example, Rodgers explains that high ash content in coking coal is a disadvantage because it decreases the calorific power of the coke product as well as increasing the amount of coke and limestone required to produce pig iron.[34] Ultimately, this technical information is drawn together with cost information to explain the dominance of the Donbas coal region, which, despite its lower quality coal, has been the leading coking region. Considering the difficulties of placing this discussion of coking coal and steel production in the context of the Soviet political economy, Rodgers does an excellent job of analyzing the prospects for changes in the locational pattern of the steel industry and of the railroad lines that tie it with its supply of coking coal.

The work of two geographers, Earl Cook and Daniel Luten, deserves attention here, for they have been the leaders in pursuing energy as a geographic research interest. Earl Cook has stated his view of energy as an area of geographic concern in the following terms:

> "Energy is the most important physical element of what geographers call the man-environment system. The analysis of energy in the context of this system and the search for practicable answers to human problems involving energy cannot be carried out adequately within such restricted frames as those of traditional economic, or of thermodynamic engineering, or of social or political management. This is a geographic subject, requiring the actual or ascribed abilities of geographers to synthesize relevant information for modelling man-environment relations."[35]

Cook employs a broad definition of energy that encompasses agriculture (food as a source of energy for humans) and he discusses basic resource availability and the location of renewable and non-renewable energy sources throughout the world. In particular, Cook deals with the American energy economy (see Figure 1-7) and the flows of energy in industralized countries in general.[36] A specific aspect of energy production and consumption that Cook discusses is that of the technical efficiency of electricity. Because electricity is less efficient overall than direct fuel use in certain end uses (e.g., heating water), it takes more energy per unit of end use output if electricity is used. Specifically, the technical efficiency of certain electrical devices such as resistance heaters is 100 percent, but overall it is only 32 percent efficient (compared to 60-90 percent efficiency of direct fuel use) due to the losses involved in electricity generation.[37] Our increased

FLOW OF ENERGY THROUGH THE U.S. ECONOMY, 1976



Source: Cook, Earl, *Energy: The Ultimate Resource?*, Washington, D.C., Association of American Geographers, 1977

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Fig. 1-7

reliance on electricity as an energy source is thus ultimately reflected in the changes in the ratio of total energy used to the gross national product. This information on the technical efficiency of electricity (which has implications for growth-related issues that Cook only touches upon) represents a portion of a well documented overview of the major facets of energy production and consumption.

Overall, Cook must be viewed as only having contributed to the traditional descriptive economic geography of energy for although he offers some evaluation and insight into the processes involved in the energy economy, his work does not extend to an analysis of the political economy of energy. Significantly, however, he does recognize the need for considering the ethical, moral and social implications of energy use.[38] This type of broad geographic research on energy illustrates that electricity represents only a portion of a complex worldwide energy system.

Daniel B. Luten provides a counterbalance to the work of Cook.[39] His approach differs in his emphasis of the patterns on the land which are created by the ways people utilize different forms of energy. In particular, he links technological innovations, notably the heat engine, small electric motors and the automobile, that radically alter our ability to use energy with changes in the visible landscape and in the location of economic activities. The transportation and storage problems of various energy forms are of central concern, revealing Luten's consideration of how the complex processes involved in the production of energy have affected the landscape. One aspect of electricity production that Luten notes is the interconnection of electricity grids in the United States. These interconnections enable utilities to more reliably meet the need for a reserve margin to handle unexpectedly high peak demands as well as to balance the economics of electricity produced from different fuels.[40]

To conclude this brief survey of geographic contributions to the study of energy, we must mention the theoretical work which bears upon the problem of energy facility study. While classical location theory, specifically, industrial location theory, contains major elements that pertain to energy facility siting, industrial location theory alone does not completely satisfy our need for a theoretical foundation because it is primarily concerned with private enterprise. Since electricity production involves the public sector as well as the private, we must also examine public facility location theory. Energy facility siting falls neatly between these two areas of theory, for it bears characteristics of both. This relationship and the body of public facility location theory is thus considered in detail in Chapter Two.

FOOTNOTES, CHAPTER ONE

1. Quality refers to the efficiency at the end use, which for some electrical devices, such as electrical resistance heaters, is 100 percent.

2. Baseline capacity is the generating capacity which operates to serve the base load, which is the minimum load of a utility over a given period of time. Usually baseline capacity operates continuously.

3. Edwin Vennard, The Electric Power Business, (New York, McGraw Hill Book Company, Inc. 1962), p. 249.

4. Banking is the practice of one utility, A, supplying electricity to utility B at times of low demand using baseload capacity, so that the utility A may draw back from utility B when it needs peaking power in high demand periods. The electricity is not "saved" but is produced from different types of capacity at different times.

5. Energy exchanges refers to short term (usually 24 hours) borrowing and returning of electrical power between utilities. Usually this is a costly way of meeting peak demands.

6. The major English references on time geography include:

   T. Carlstein, A Time-Geographic Approach to Time Allocation and Socio-Ecological Systems, (Lund, Lunds Universitets Kulturgeografiska Institution, Rapporter och Notiser, 20, 1975); T. Hagerstrand, "What About People in Regional Science?" Papers of the Regional Science Association, 24 (1970), pp. 7-21; T. Hagerstrand, On Socio-Technical Ecology and the Study of Innovations, (Lund, Lunds Universitets Kulturgeografiska Institution, Rapporter och Notiser, 10, 1974); T. Hagerstrand, The Impact of Transport on the Quality of Life, (Lund, Lunds Universitets Kulturgeografiska Institutuion, Rapporter och Notiser, 13, 1974); T. Hagerstrand, "Space, Time and Human Conditions," Dynamic Allocation of Urban Space, ed. by A. Karlqvist, L. Lundquist, and F. Snickars, (Lexington, Saxon House Lexington Books, 1975); T. Hagerstrand, "Survival and Arena: On the Life-History of Individuals in Relation to their Geographical Environment," The Monadnock, 49 (1975), pp. 9-20; A. Pred, "Urbanization, Domestic Planning Problems and Swedish Geographic Research," Progress in Geography, 5 (1973), pp. 1-76; A. Pred, "The Choreography of Existence: Comments on Hagerstrand's Time-Geography and Its Usefulness," Economic Geography, 53 (no. 2, April 1977), pp. 207-221.

7. See for example, Janet L. DePree, The Wheelchair-Bound: A Time Geographic Perspective, (unpublished masters thesis, University of California, Berkeley, 1979) and Roger P. Miller, A Time Geographic Assessment of the Impact of Horsecar Transportation on Suburban Non-Heads-of-Household in Philadelphia, 1850-1860, (unpublished Ph.D. dissertation, University of California, Berkeley, 1979).

8. Energy Analysis Program, Analysis of the California Energy Industry, (Berkeley, Lawrence Berkeley Laboratory, University of California, 1977), p. 4.

9. California Energy Commission, Choices for California . . . Looking Ahead, (Sacramento, California Energy Commission, 1979), p. 14.

10. Energy Analysis Program, p. 7.

11. California Energy Commission, p. 14.

12. Ibid., p. 15.

13. Norman B. Livermore, Jr., Energy Dilemma: California's 20 Year Power Plant Siting Plan, (State of California, Resources Agency, June 1973), p. 1.

14. Peak demand is the maximum amount of energy consumed in any consecutive number of minutes (e.g., 15 or 30) during the month.

15. California Energy Commission, p. 23.

16. Ibid., p. 28.

17. Ibid.

18. Ibid., p. 32.

19. Frank J. Calzonetti, An Evaluation of Alternative Strategies for Siting Coal Gasification Facilities in the United States, (unpublished Ph.D. dissertation, University of Oklahoma, 1977).

20. Ira M. Sheskin, "Alaskan Natural Gas: Which Route to Market?" The Professional Geographer, 30 (May 1978), pp. 180-189; J.P. Osleeb and I.M. Sheskin, "Natural Gas: A Geographical Perspective," Geographical Review, 67 (1977), pp. 71-85.

21. For example, Edward Malecki, University of Oklahoma; David Kirtland, C. Gregory Knight , Diane Mach, University of Pennsylvania; Sidney Jumper and Bruce Ralston, University of Tennessee; Frank Calzonetti and Harley Johansen, West Virginia University.

22. Thomas J. Wilbanks, "Geographic Research and Energy Policy Making," Geographical Survey, 7 (October 1978), p. 11.

23. John I. Clarke, "Oil in Libya, Some Implications," Economic Geography, 39 (no. 1, January 1963), pp. 40-59.

24. Aloys A. Michel and Stephen A. Klein, "Current Problems of the Soviet Electric Power Industry," Economic Geography, 40 (no. 3, July 1964), pp. 206-220.

25. R.C. Riley, "Changes in the Supply of Coking Coal in Belgium since 1945," *Economic Geography*, 43 (no. 3, July 1967) pp. 261-270.

26. Alexander Melamid, "The Geography of the Nigerian Petroleum Industry," *Economic Geography*, 44 (no. 1, January 1968), pp. 37-56.

27. L. King, E. Casetti, J. Odland, and K. Semple, "Optimal Transportation Patterns of Coal in the Great Lakes Region," *Economic Geography*, 47 (no. 3, July 1971), pp. 401-413.

28. D.A. Brown and D.S. Simonett, "Integration and Locational Change in the Australian Electricity Industry: 1951-1965," *Economic Geography*, 43 (no. 4, October 1967), pp. 283-302.

29. *Ibid.*, p. 284.

30. *Ibid.*, p. 288.

31. *Ibid.*, p. 294.

32. *Ibid.*, p. 297.

33. Allan Rodgers, "Coking Coal Supply: Its Role in the Expansion of the Soviet Steel Industry," *Economic Geography*, 40 (no. 2, April 1964), pp. 113-150.

34. *Ibid.*, p. 122.

35. Earl Cook, *Energy: The Ultimate Resource?* (Washington, D.C., Association of American Geographers, 1977), p. viii.

36. Earl Cook, "The Flow of Energy in an Industrial Society," *Energy and Power*, (San Francisco, W.H. Freeman and Co., 1971), pp. 83-94.

37. *Ibid.*, p. 84. An example of this is water heating. It takes 234,000 Btu of natural gas (227.5 cubic feet) to produce electricity, transmit it and use it in an electrical resistance water heater, while it requires only 121,000 Btu of natural gas (117.5 cubic feet) in a gas water heater to heat the same amount of water to the same temperature.

38. Earl Cook, *Man, Energy, Society*, (San Francisco, W.H. Freeman and Co., 1976).

39. Daniel B. Luten, "The Economic Geography of Energy," *Energy and Power*, (San Francisco, W.H. Freeman and Co., 1971), pp. 109-120.

40. *Ibid.*, p. 115.

CHAPTER TWO: LITERATURE REVIEW OF PUBLIC FACILITY LOCATION THEORY

Electrical utilities, even if privately owned, are public in the sense that they are government regulated monopolies providing a public service. Identifying the meanings which "public" and "private" connote is necessary before reviewing public facility location theory literature. First, "public" and "private" may be used to describe the ownership of an organization that provides goods or services. Second, the terms may be used to classify goods or services into those which are private (and thus primarily supplied by the private sector) and public goods (which are provided by both public and private organizations). The distinction here is an important one, for most public facility location theory deals with public goods and usually assumes public ownership. Whether or not the supplying organizations are in fact publicly owned is often not noted. In fact, the work done on the location of hospitals, for example, does not seem to make a distinction between public and private ownership of supplying organizations. But the question of ownership is important because if one assumes a publicly-owned organization, the traditional economic assumptions about goals and decision-making behavior (namely, the goal of profit maximization) must be replaced by goals suited to a non-profit organization, such as satisfying the needs of the population served. In the case of the electrical utilities, it is an especially important distinction because electricity is a public good and the provision of electricity is a public service. Government controls on rates and location decisions are evidence that electricity is a public good. In California, the electrical utilities are governed by the California Public Utilities Commission (CPUC) and the California State Energy Commission.

In debates about the role of government in regulating electric utilities, the question of whether the electrical utilities should be publicly or privately owned is often raised. The primary argument in favor of public ownership is that without a need for profits, electricity can be produced and supplied more cheaply. The argument of privately owned utilities is that these organizations can more efficiently produce the electricity by maintaining and developing the best possible technology. Usually, this argument is more generally stated in terms as support of a free enterprise economy.

In the United States, the private investor owned utilities are clearly the dominant form. In 1975, 315 private utilities had 78.8 percent of the generating capacity and 78.3 percent of the 81,892,000 customers.[1] The reasons behind this dominance go back to the early days of the electircal utility industry. The gas companies, which were largely privately owned, were often the direct predecessors to the electrical utilities, and thus set a precedent for private ownership. Financial risk was high in the early days of electricity production and the private companies undertook the risks while the governments displayed little interest in doing so.[2] Perhaps the most important reasons that public ownership never succeeded on a wide scale was that prices declined steadily with continued technological improvements. The trend of declining products costs persisted into the 1960's. With such an impressive cost record, the utilities were not often threatened by proposals for public ownership. The utilities, however, protected their self-interest by fighting any movements toward public ownership through propaganda and the formation of trade associations.[3] The view of the Pacific Gas and Electric Company (PG&E) is representative: "PG&E's position at all times has remained essentially the same—that of a staunch defender against political invasion of a business successfully created and maintained by individual initiative and developed according to the needs of a growing state."[4] In fact, government ownership has been successful only at the municipal level, and in a few instances, at the regional level (for example, the state of Nebraska and the Tennessee Valley Authority), although recently interest in public ownership has resurfaced.[5]

Because this study is focused on the role of interdependence and government regulation, the classification of organizations as privately owned is less important than the fact that they provide a public service. Although one might argue that the ownership of the utilities affects their locational decision-making behavior (because the privately owned ones are still concerned with making profits), this difference is outweighed in importance by the responses these organizations must make to governmental regulations regardless of ownership. Thus, "public facility" here refers to those facilities concerned with the production and distribution of public goods regardless of whether the supplier is publicly or privately owned.

Classical Location Theory

In order to place the discussion of public facility location theory in context, it is necessary to first briefly review location theory in general, and evaluate its relevance to the electrical utility location problem. Classical location theory deals with three types of economic phenomena: agricultural activities,[6] industrial and manufacturing activities,[7] and tertiary activities, or the provision of goods and services.[8] Only industrial location theory pertains to the electrical utility problem and does so only insofar as energy facilities resemble industrial facilities. The similarities are important to note, especially since any previous geographic writings concerned with electrical utilities have been a sub-area of industrial location theory.[9] While certain kinds of electricity generation are confined to some locations by the nature of the fuel source—like geothermal and hydroelectric units—the fossil fuel and nuclear-powered units provide some locational choice to the utility.

Three relevant aspects of industrial location theory need to be considered here. First, the traditional Weberian type of analysis, with its emphasis on the cost of transporting raw materials, is simply too limited in its assumptions to be of use in this complex problem; indeed, it is even heavily criticized for its limitations in dealing with traditional industrial problems.[10] While the discussion of weight-losing, weight-gaining and pure-weight materials pertains mainly to manufacturing establishments with discrete products, it does provide a gross analogy to the electric utility industry problem of comparing the costs of transporting fuel to the costs of transmitting electricity. Given transmission losses (approximately 3 kilowatts of electricity are lost for every hundred miles of transmission), it is necessary to ask which is more efficient— minemouth generation or generation located near the market (the "load center")? If only this simplified view of factors is included in a siting analysis, then industrial location theory in its more sophisticated forms offers a guide to deciding where to locate an electrical generating facility.

Secondly, industrial location theory includes explicit consideration of the market area of a firm, but this is not relevant to the electric utility location problem. Losch's work on profit maximization led to his city-rich and city-poor zones with hexagonally-shaped market areas. This work, modified by Isard and Greenhut,[11] suggests the importance of locational interdependence in determining market areas. In theoretical considerations in industrial location decisions, a basic concern is to determine the effects and to measure success in serving a particular market. This important area of concern in industrial location theory is not pertinent to the electric utility problem because it is a monopolistic industry whose market areas or service areas have been formed by the consolidation of many smaller companies during the early decades of the industry. These service areas have remained more or less stable for many decades. The consolidation of companies to form the Pacific Gas and Electric Company's service area serves as an illustration of this nationwide phenomenon (Figure 2-1).[12] Today, competition exists only on the border areas of utility service areas where electricity is not yet provided (Map 2-1).[13]

The third and most important conclusion arising from an evaluation of industrial location theory is that it is insufficient for dealing with electrical utilities because of its limitation to the private sector. The manufacturing concerns of location theory are usually imbued with profit maximization goals and typical private sector behavior which is not characteristic of electric utilities. This difference between private sector firms and regulated monopolies is in fact a more general statement of a difference of which the market area problem is a specific example. In the earlier part of this century and up through

Figure 2-1

THE "FAMILY TREE"
PACIFIC GAS AND ELECTRIC COMPANY

Pacific Gas and Electric Company today represents the amalgamation of approximately 520 predecessor companies and miscellaneous properties by a progressive process of consolidation during the past 100 years. In abbreviated form, the lines of descent of the principal corporate gas and utility groups absorbed into the present Company in past years are here indicated. Each group in turn consisted of many other companies. Numerous individual organizations and systems have been acquired directly by P. G. and E.

The first date after a company name is that of incorporation; the second date is when stock control was obtained by the company's successor. Indentation signifies that the company or companies were antecedents or components of the first named.

PACIFIC GAS AND ELECTRIC COMPANY

Incorporated October 10, 1905

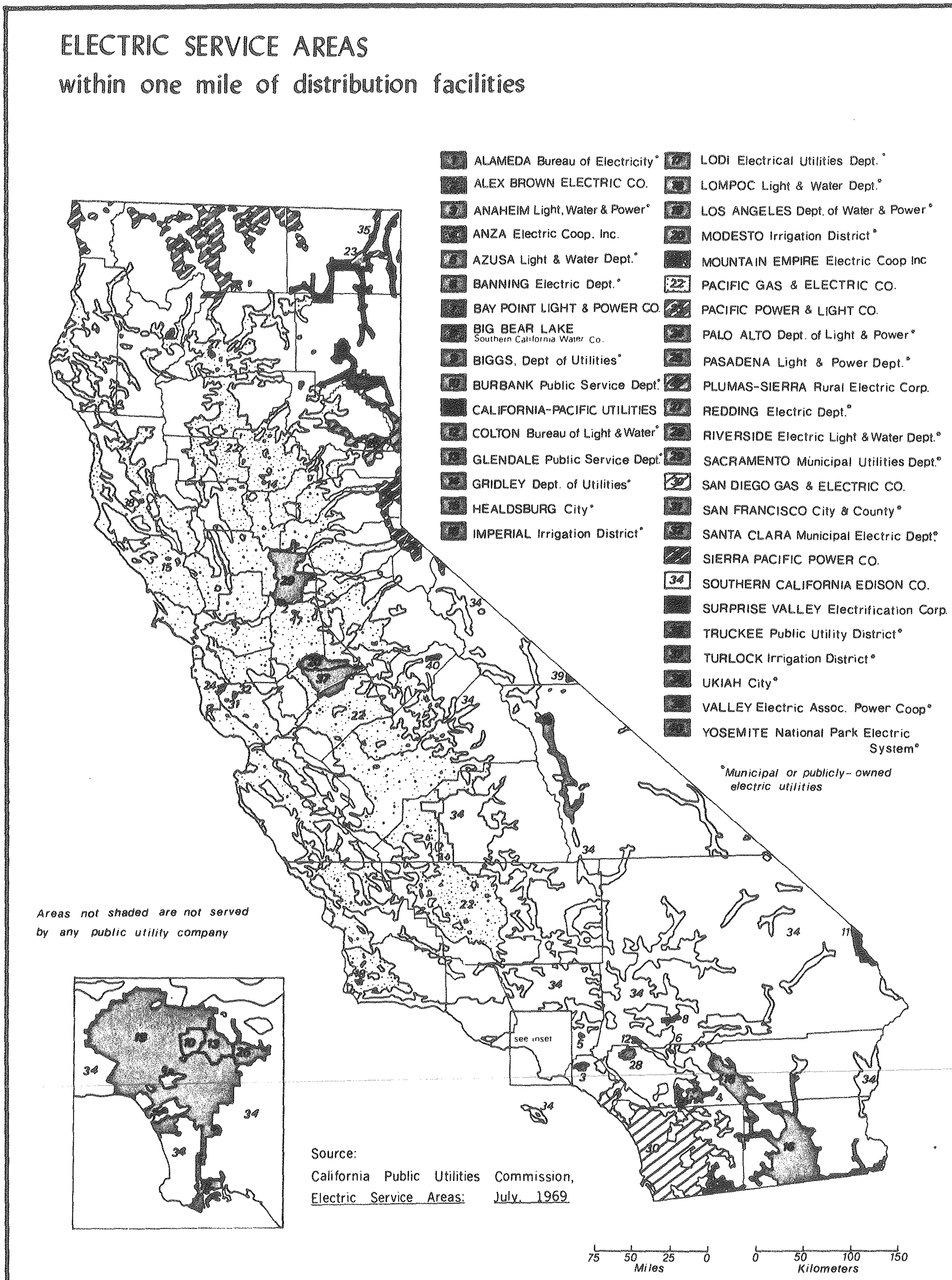
Calif. Gas and Elec. Corp.	1901-1906
Bay Counties Power Co.	1900-1903
Nev. County Elec. Power Co.	1892-1900
Valley Counties Power Co.	1902-1902
California Central Gas and Electric Company	1901-1903
South Yuba Water Co.	1890-1905
Standard Elec. Co. of Calif.	1897-1904

San Francisco Gas and Elec. Co.	1896-1906
San Francisco Gas Light Co.	1873-1897
San Francisco Gas Co.	1852-1873
Edison Light and Power Co.	1891-1897
California Elec. Light Co.	1879-1891

Great Western Power Company of California	1915-1930
Great Western Power Co.	1906-1915
Western Power Co. of Calif.	1902-1906
Northern Calif. Power Co., Consolidated	1908-1919
Northern Calif. Power Co.	1902-1908
Sierra and San Francisco Power Company	1909-1927
Coast Valleys Gas and Electric Co.	1912-1927

San Joaquin Light and Power Corporation	1910-1930
San Joaq. Lgt. and Power Co.	1905-1910
San Joaquin Power Co.	1902-1905
San Joaquin Electric Co.	1895-1902
Midland Counties Public Service Corporation	1913-1930
Western States Gas and Elec. Co.	1910-1927
Calif. Telephone and Light Co.	1911-1923

Source: Charles M. Coleman, <u>PG&E of California: The Centennial Story of the Pacific Gas and Electric Company 1852-1952</u>, (New York, McGraw Hill Book Co., Inc., 1952), p. 343.


ELECTRIC SERVICE AREAS
within one mile of distribution facilities
ALAMEDA Bureau of Electricity*
ALEX BROWN ELECTRIC CO.
ANAHEIM Light, Water & Power*
ANZA Electric Coop. Inc.
AZUSA Light & Water Dept.*
BANNING Electric Dept.*
BAY POINT LIGHT & POWER CO.
BIG BEAR LAKE
Southern California Water Co.
BIGGS, Dept of Utilities*
BURBANK Public Service Dept.*
CALIFORNIA-PACIFIC UTILITIES
COLTON Bureau of Light & Water*
GLENDALE Public Service Dept.*
GRIDLEY Dept. of Utilities*
HEALDSBURG City*
IMPERIAL Irrigation District*
LODI Electrical Utilities Dept.*
LOMPOC Light & Water Dept.*
LOS ANGELES Dept. of Water & Power*
MODESTO Irrigation District*
MOUNTAIN EMPIRE Electric Coop Inc
22 PACIFIC GAS & ELECTRIC CO.
PACIFIC POWER & LIGHT CO.
PALO ALTO Dept. of Light & Power*
PASADENA Light & Power Dept.*
PLUMAS-SIERRA Rural Electric Corp.
REDDING Electric Dept.*
RIVERSIDE Electric Light & Water Dept.*
SACRAMENTO Municipal Utilities Dept.*
SAN DIEGO GAS & ELECTRIC CO.
SAN FRANCISCO City & County*
SANTA CLARA Municipal Electric Dept.*
SIERRA PACIFIC POWER CO.
34 SOUTHERN CALIFORNIA EDISON CO.
SURPRISE VALLEY Electrification Corp.
TRUCKEE Public Utility District*
TURLOCK Irrigation District*
UKIAH City*
VALLEY Electric Assoc. Power Coop*
YOSEMITE National Park Electric System*
*Municipal or publicly-owned electric utilities
Areas not shaded are not served by any public utility company
see inset
Source:
California Public Utilities Commission,
Electric Service Areas: July, 1969
75 50 25 0
Miles
0 50 100 150
Kilometers

Map 2-1

the early 1950's, the electric utility industry bore a minimum of governmental regulation. In this period, regulation was confined to price controls and little, if any, control was extended over the spatial decision-making of the utilities. In this period, the problems considered in industrial location theory would have been more similar to the electric utility location problem because both emphasized efficiency in production. Given that electricity prices were controlled, the electric industry had increased incentive to hold down production costs.[14] Now, however,with the great increase in the regulation of the siting process, industrial location theory bears less and less relevance to the electric utility location problem. Thus the emphasis on regulating utilities because they are a public concern suggests that the electrical utility location problem belongs to the area of public facility location theory. Finally, we must note that the complexity of the electrical utility location problem in general precludes adequate consideraion of this problem through the use of traditional economic location theory.[15]

Public Facility Location Theory

It is necessary to begin by comparing the basic characteristics of public facility location theory to the basic attributes of the electrical utility location problem. Because public facility location theory can perhaps provide the pertinent theoretical foundation for the present study, we must evaluate the appropriateness of such theory for this purpose.

First, the majority of the theoretical work in public facility location theory is focused on the urban scale of observation because the types of public services which are treated are offered in metropolitan areas in sufficient quantity to form a pattern of geographic interest. These services include hospitals, schools, police and fire protection, ambulance services, libraries, and recreational facilities. Second, due to the nature of these services, proximity to the facility is considered important, either for ease in utilizing the facility if the service is offered at the facility or because proximity will mean valuable time is saved in the case of emergencies. Neither the urban scale of observation nor proximity to the facility are relevant to the electrical utility location problem. The scale of observation that is important here is that of the region or service area, not the urban area. Since electricity is distributed to individual buildings, proximity to the power plant or related energy facilities is not only unnecessary but also undesirable because the energy facilities are noxious. They are noxious in their air, water and noise pollution, and are thus both unattractive and unhealthy. The noxious qualities of energy facilities are in fact a major problem in the siting decision-making process and provide a partial explanation of why government regulation of the process has increased in recent years (this is discussed more fully in Chapter 3). In addition, it should be noted that some other public services are also noxious, such as sewage treatment plants, garbage disposal sites or collection areas, water treatment plants and water supply reservoirs.

Third, public facility location theory in general employs time and distance as surrogates for determining optimal locations and measuring the use of a facility. Since use can be assumed to be an inverse square function of the distance from a facility, there is an emphasis on the spacing and number of facilities necessary to meet the demand of the population, given certain basic assumptions. Often, being able to serve the population within a certain distance and/or time is equated with optimizing social welfare. Equity considerations and social concerns are indirectly dealt with by assuming that relationship. For example, a normative assumption could be that no person should have to travel more than N miles to a hospital or health care center. It if can be shown that a certain pattern of facilities makes this possible, then that pattern optimizes welfare in a limited sense. In the case of electricity, however, time and distance factors can be offered neither to explain consumption nor to demonstrate that social welfare has been met. Moreover, these factors are often inadequate to account for consumption or to evaluate social welfare even for the services for which these measures were developed. For example, because people do not always travel to the nearest center for service, as is often assumed, other explanations are needed to understand spatial behavior.

The behavior of hospital patients provides a specific illustration. Although in the planning and spacing of health care centers, especially maintenance organizations, it is often thought that people prefer nearby centers, empirical research indicates that other factors are more important. If a patient prefers a particular physician, he may travel farther than may be otherwise expected since physicians are usually associated only with selected institutions. Furthermore, if a patient belongs to certain health care plans (for example, the Kaiser Foundation), only certain designated facilities will be used, even if other hospitals occur as intervening opportunities. The perceived quality of the institution also affects the patient's choice. Finally, religious preferences may compel people to seek out and choose a health care facility that necessitates travelling further than might be suspected prima facie.[16]

Fourth, for more public services, the service is provided without directly charging fees; public libraries, schools, police, and fire departments serve as illustrations of this. These services instead are paid for indirectly through taxation. Electricity, however, is directly billed to the consumer in proportion to the amount consumed as determined by a variety of pricing structures.[17] While other public services may involve a fee (for instance, water treatment), it is true that most do not and thus cost considerations do not enter into the theory as major components. We will see in later chapters, however, that cost has become an important aspect of the electrical utility location problem due to economies of scale, increased difficulty in raising capital requirements, as well as the direct effects of cost on consumer demand behavior.

Fifth, the concern for equity and efficiency which is characteristic of public facility location theory literature is a less obvious concern in the electrical utility location decision. It is undeniable that there are significant social costs associated with energy production: boomtown effects,[18] health effects, and environmental degradation to name but a few. These social questions, however, are not resolved by resorting to some "optimal" pattern of facility distribution because accessibility to the facility is not an effective measure of social welfare. Comments pertaining to work on equity and efficiency considerations will clarify this point.

A last note in this comparison of characteristics concerns mathematical representation in the theory. For most purposes, public facilities can be represented as distinct points on a plain. But for the electrical utility industry this is insufficient, for, in addition to power plants and ancillary facilities, there is also the complex network of transmission lines which requires network representation.

These outlined differences between the characteristics of established theory and the attributes of the electrical utility location problem demonstrate that some advances and adjustments are necessary for this theory to be applicable to the present problem. The examination of the siting process in California and the role of system interdependence in the locational decision-making process will point the way to suggesting improvements to be made in the present theories.

The first important conceptual contribution on public facility location was Michael Teitz' paper, "Toward a Theory of Urban Public Facility Location," published in 1968.[19] He noted that until that time the location of public facilities had received scant attention as an area of theoretical concern. The problem had either not been considered, or had been dismissed as a special case of commercial location, despite the important differences in the characteristics of the location problem. Two important features of Teitz's paper are worth noting: the differences he points out between the problem of urban public facilities and those of the private sector and the need to classify facilities.

Teitz defined urban public facilities as those "components of the city whose primary function is to facilitate the provision of goods and services declared, to be wholly or partly within the domain of government."[20] Here public ownership is explicitly noted. This definition encompasses a wide range of services, including, among others, schools, public libraries, the water supply system and the Post Office. These facilities may be classified in a variety of ways—as the following discussion of the literature demonstrates—but Teitz remarks on two: the classification of their outputs as public goods, zero short-run marginal cost goods or merit goods; and the classification of the geometric properties of each system of facilities. In the latter case, point patterns would represent hospitals or schools while networks would represent water supply systems, sewers, and electricity systems. This particular classification is used by others as a first approximation for grouping not only urban public facilities but private ones as well.[21] Finally, Teitz comments on the hierarchical property of some of the services (or goods) provided. This is directly analogous to Christaller's distinction between higher and lower order goods. As an illustration, consider that some fire stations have specialized rescue squads as well as the standard or lowest order service of a fire truck. In the case of network functions, there are discrete junctures at which the good or service is stepped down (or up), such as a transformer substation which reduces the voltage of the electricity supplied from the power plant.

The differences between private and public sector facilities which Teitz suggests bear examination. How does each relate to the electric utility problem? First, the location and scale of expenditures is determined by a public or quasi-public process. This occurs in the absence of a competitive price system, which is usually the mechanism by which resources and expenditures are allocated in the private sector. Teitz suggests that this may indicate the usefulness of welfare economics and the economics of public finance. These expenditures, allocated from governmental budgets derived from taxation, indicate a price zero system; the consumer does not pay a direct fee for the services (for example, schools, library and fire protection). This is not the case, however, for the electrical utilities (either private or public). Teitz, although he mentions services and goods such as gas, telephone, water and electricity, does not deal with the pricing system of these utilities. This price zero concept is applicable to a wide range of urban public facility goods and services, and leaves only the distance to be travelled or the time for travelling to a given facility as the cost to the consumer.[22]

Questions of rate structures for public utilities, which have gained a wide treatment in traditional regulatory economics, are important because of the effects that the pricing policies for electricity ultimately have on the siting process for electrical facilities.[23] The value of Teitz's work does not rest solely in his exposition of basic concepts or in the mathematical model he presents. Perhaps the most important contribution that Teitz has made is to spark the interest of other scholars in the area of public facility location theory.[24] Teitz's paper, whose appeal is in part due to the clear way in which the problem area is introduced and discussed, anticipated the resurgent interest in the locational problems of the public sector, and thus provided a guidepost to subsequent endeavors in this area of research.

A significant portion of the public facility location theory literature uses an operations research approach. This sub-literature is often referred to as the location allocation literature. Scott sets out the general structure which characterizes the approach:

> Suppose that there are given: (a) a set of n points distributed in the plane; (b) a numerical weight to be attached to each point; and (c) a set of m indivisible centroids without predetermined locations; then, the location-allocation problem, in its most general form, is to find locations for the m centroids and an allocation of each point, or fraction of a point, to some centroid so as to optimize an objective function.[25]

This general formulation allows many different activities to be designated for the centroids as well as providing for different definitions of objective functions. The most commonly used objective function is that of cost minimization. The basic location-allocation problem which has been described can be broken down into the classic transportation problem of linear programming where the locations of the central facilities are known and the flows must be assigned (also known as the regional assignment problem),[26] and the Weberian problem of determining a central facility location that minimizes the cost of the flows.[27] While the solutions to these problems are well understood, it is difficult to solve optimally the location-allocation problems that have complex non-linearities. Solutions for these more complex problem formulations, which may be divided into those which are tree-searching and those which are heuristic, have generated a substantial literature.[28]

The task at hand is not to compare and evaluate the details of the various methods, but to determine the limitations and applicability of this formulation for the present problem. Even for those who are primarily interested in location-allocation problems, the limitations of the solution methods present major difficulties.[29] That the real world "tends to defy exact analogs"[30] is an understatement. Succinctly stated, the location-allocation models, even in their most sophisticated forms, do not mirror reality to a sufficient degree to be useful in considering the electric utility problem. Important factors in the spatial decision-making process of the electric utilities, especially the regulatory framework in which the decisions are made, have not been incorporated into the models. This is not to say that these models have little or no value, but there is an underlying fundamental philosophical conflict which makes using such models for the electric utility location problem difficult. The conflict is one between normative theory and a theory that attempts to replicate reality in accurate, if simplified, terms. We must determine if accepting the need for a normative theory is in fact "reasonable." Why do scientists, geographers in particular, want normative theory and what questions does such a theory answer? The difficulty facing the geographer is outlined by Gunnar Olsson:

> "Unfortunately, the advocated role of the social scientist is severely hampered by the fact that the ideal schema of scientific explanation rarely applies to the real world; knowledge is incomplete, correspondence rules and measurements are inexact, and even the notion of the investigator's objectivity is debatable. Still, most social research seems to assume away these unpleasant stumbling blocks in attempts to force theories and empirical observations into the stringent frameworks of logical positivism and standard Aristotelean logic."[31]

Beyond the problems of reflecting reality accurately in logical positivistic models, geographers have noted the importance of the role of normative theory in their research. Ross MacKinnon stated in 1970 that geographers seem to have neglected normative theory and that this neglect should be rectified. His discussion of dynamic programming was intended to point geographers in this direction.[32] Michael Chisholm has made a case for a return to normative theory as a basis for location theory. He stated: "Current fashion is rather against the idea of normative theories and is setting strongly in the direction of positive, usually stochastic, models. However useful this vogue may be in dealing with urgent and important problems of decribing what 'is' and forecasting what 'will be,' it will give us no insight into what 'should be.'"[33] It is important to digress and be clear as to what lies beneath this goal of a normative location theory. In stating what "should be," we are declaring what things we value, what we wish to see valued by others and what goals we think ought to be sought by society as a whole. In short, we make value judgments.

The philosophical debate concerning "scientific objectivity" and hidden values in the supposedly value free methods of "science" is vital. The need for explicitly labelling values is important given the purpose to which Chisholm envisions normative theory being applied: planning. Normative theory, by setting forth a clear picture of what ought to be, provides planners and other agents seeking to change society (for example, legislators, business people and other government officials) with a map of the desired end state, formulated in such a way as to aid those actors to conform to the desired end state.[34] Nelson argues that the recognition of value judgments is essential if planners are to explicitly reflect on the moral and ethical implications of the changes they are implementing.[35] Olsson also supports this view by stating that "responsible social engineering should be based on a combination of scientific knowledge and visionary politics."[36] In order for people to make informed choices about changes in society, it is necessary to have a reflective planning community. While Chisholm states that normative theory cannot be generated from observing behavior, he nevertheless expects that normative theory "ought to start from sensible assumptions, which can be checked by empirical observation." However, there is no proof that one set of assumptions is inherently better as the basis for postulating normative theory than is another.[37] Chisholm describes the problem as a "metaphysical matter, a question of belief . . . not amenable to scientific analysis."[38] This is the only statement that Chisholm makes regarding value judgments and since it occurs in a different work, its absence from his later work weakens his argument for a normative theory.

Given this digression, let us consider what Chisholm specifies in his normative location theory. He calls for theories at a macro-scale which would encompass regions or at least the interrelationship between urban centers. It is in connection with discussing the advantages of a macro-scale perspective that Chisholm suggests that such a theory would be a planner's view of society.[39] While it would be unfair to accuse Chisholm of totally neglecting the role of value judgments, it is not encouraging to note that he further states that once the desirable end state is delineated (that is, the value judgments have been made explicit) that it is possible (indeed, "compatible") to approach the solution with linear programming. To specify the quantities of final goods and services to be produced and to outline which input-output coefficients are applicable is to make a value judgment. This is especially true in determining the need for an energy facility, for a person who values conservation will suggest solutions quite different from someone who does not. In particular, the techniques (such as linear programming) associated with the operations research approach give the illusion of scientific objectivity to problem matter that is explicitly constructed of value judgments on the part of the researcher.

Chisholm undermines the strength of purpose for a normative location theory by suggesting that it be static and include conditions of certainty:

> "Given the present state of the relevant arts, it is probable that normative theory must be static and not dynamic. The moment that growth paths, and paths of change, are postulated, uncertainty finds the door wide open and comes bouncing in. Uncertainty is a deadly enemy of normative thought and must therefore be banned. This does of course present a serious problem in the use of normative theory, since it is desirable not only to identify the desired final state but also the path whereby this may be achieved. Perhaps this is a clear case where ambition must be curbed and where we must learn to be content to live with abstract ideas whose application to real-world conditions is not always apparent or easy. If this is so, the most that can be hoped for is a static equilibrium under conditions of certainty."[40]

This removes the normative theorist from reality, not only in the concoction of the theory, but also perhaps in its use. If a "static equilibrium under conditions of certainty" is the best result, then pursuing a normative theory of public facility location will not help us understand what is happening in the "real" world.

Massam offers a different, but equally limited, argument for pursuing normative theory. He suggests its value lies in making real world model comparisons in order to measure the costs incurred by having facilities that are not ideally located.[41] Similarly, Hodgart suggests that "by showing that better solutions exist, they give the community group a stronger case against inefficient and inequitable proposals."[42] Again, the term "better" is used without the qualification it needs. Given the limitations of normative theory, it is doubtful this justification can be true. Since understanding the decision-making process of the California electrical utilities is the problem undertaken here, it is clear that normative theory cannot play a central role or act as a foundation in formulating the approach to the task.

If one accepts, however, that a normative theory is necessary, then the location-allocation sub-literature would seem a fruitful place to start. We could formulate our problem of siting energy facilities in dynamic systems terms, with an emphasis on the problem of how to optimize in the long run a system to which facilities are added over a long time period.

One example of the location-allocation approach to the electrical utility problem is Dutton, Hinman and Millham's article, "The Optimal Location of Nuclear-Power Facilities in the Pacific Northwest."[43] Optimal location is defined "with respect to capital-construction, operating, and transmission costs."[44] This paper sets out economically viable options while recognizing that actual plant locations are determined by political realities. Accordingly, the major problem of political realities is set aside and several simplifying assumptions are made. These include representing the demand for electricity as being within a small number of load centers rather than dispersed, and assuming that the overall system that meets both baseload and peak demand will be optimized.[45] A set of possible plant sites and the cost of building a 1000 megawatt power plant are specified at the outset. Site dependent operating costs vary according to the cooling technology and thus consist of pumping costs, fan-power costs, water-treatment costs and tower-maintenance costs.[46] Dutton et al. calculate the portion of expected peak demand (projected to 1992) that must be met by nuclear, assuming rates of growth from 4 to 7 percent annually. Then the problem is given the following expression:

Minimize

$$\Sigma_{i=1}^{i=13} f_i y_i + \Sigma_{i=1}^{i=13} \Sigma_{j=1}^{j\ \ 8} C_{ij} y_{ij} + \Sigma_{i=1}^{i=13} C_i \Sigma_{j=1}^{j=8} x_{ij}$$

subject to the following constraints:

$$\Sigma_{j=1}^{j=8} y_{ij} \leqq 0.85\ k_i y_i$$ (an 85% capacity factor is assumed)

$$\Sigma_{i=1}^{i=8} x_{ij} \leqq k_i\ (6130) y_i$$

$$\Sigma_{i=1}^{i=13} y_{ij} \leqq d_j$$

$$\Sigma_{i=1}^{i=13} x_{ij} \geqq e_j$$

$$\tfrac{1}{2}(6130) y_{ij} \leqq x_{ij} \leqq 8760 y_{ij}$$ (6130 refers to a number of hours in a year that a plant is assumed to operate; 8760 is total number of hours in a year.)

$$x_{ij} \geqq 0$$

$$y_{ij} \geqq 0$$

$$y_i = 0 \text{ or } 1$$

where

f_i = annualized capital construction cost of plant i

d_j = demand for peak power at market m_j in kilowatts

c_i = operating cost (in mills/KWH) of a kilowatt-hour

c_{ij} = annual cost of transmitting a kilowatt from P_i to M_j

y_{ij} = number of kilowatts supplied by P_i to M_j

x_{ij} = number of kilowatt-hours supplied by P_i to M_j

k_i = 1000 MW, nominal peak capacity of P_i

y_i = 0 if P_i is not built, = 1 if P_i is built

e_j = 0.7 (8760) d_j = annual demand for energy at M_j in kilowatt hours.

The authors used the branch and bound algorithm of Sa in combination with the simplex method to solve this mixed integer programming problem. The results of these solutions for the 6 percent annual growth rate call for building all but two of the original thirteen plants. The cost difference if one of the suboptimal plants is built is $400,000 above the optimal total cost of $75,700,000. This difference is so small (0.53 percent) in comparison to the overall total that closer cost analysis would be necessary. In addition, 1100 seconds of central processing time were required on an IBM 360/67 to complete the computations. The expense of even running such a program is rather high and weakens any argument in favor of such an analysis. The difficulties the authors had in determining the cost of the plants included out of date costs that had to be raised by an estimated factor to account for both inflation and actual cost increases. The possibility of error in the cost data is so likely that the difference of $400,000 seems of questionable use in deciding whether or not one plant should be built over another. Moreover, the authors, in discussing the solution for an annual growth rate of 5 percent, note: "This cost differential between the two designs is getting close to the precision of the data and also, clearly, the decision to build P11 rather than P12 could be reversed by a relatively minor unexpected construction problem."[47] These comments suggest that the utility of this analysis is rather limited. Finally, this article could have been more accurately titled because it suggests that a subset of locations were optimally selected from a larger set of possible locations. Placing the narrowly defined optimization goal (cost minimization) in a real world context of the siting decision-making process demonstrates the limited contribution that such a study offers.

One additional area of inquiry within the location-allocation sub-literature deserves attention here. Massam, in his review of this literature, considers how intuitive solutions to the complex problems seem as good as, or perhaps better, than computer algorithms.[48] The appeal of examining the intuitive approach comes from the sheer size of the combinatorial problems. Massam cites several examples: choosing 5 sites out of 77 possible ones offers over 19 million possibilities; there exist at least 32,000 ways to connect 6 cities.[49] Clearly, even with high speed computers, these problems cannot be evaluated individually at reasonable cost. Massam suggests that a combination approach be taken in which an initial set of possible solutions is determined through intuition and the actual evaluation of each of those possibilities is conducted with the aid of a computer. Since actors in the decision-making process rely so heavily on intuition, it is reassuring to see that rudimentary empirical examination of its use displays success.

Equity and Efficiency Considerations in Public Facility Location Theory

We have observed the important differences in goals and objective functions between private and public sector models of location. The private sector is assumed to be motivated by profit while the public sector is concerned with social welfare. The concern for social welfare is normally expressed in terms of equity and efficiency questions. We will now examine several articles which deal with these issues.

Morrill and Symons have observed a concern among people working in the health care profession for a balance between the "efficiency" of a few large hospitals and the "equity" of smaller dispersed units.[50]

Efficiency, as here defined, requires either meeting a "societally predetermined level of volume of service...at minimum total system costs of operation and travel" or maximizing the volume of service within a budget constraint.[51] Morrill and Symons, in pointing out the differences between several measures of central tendency, demonstrate that each solution has implications for how different segments of the population are served. They proffer three measures of equity: 1) system average, which is a weak measure of equity because it may conceal a balance between a few very well-off members and those who are extremely disadvantaged; 2) minimum standard, in which each individual has at least some service or "no more than some acceptably small proportion of people are more than some critical distance from a good or service provided by a facility;"[52] 3) variability, that is, a measure of variation about a mean. (They argue that in terms of accessibility, those patterns with small variation are more equitable.) These measures of equity are common and may be found elsewhere in the literature.[53] Morrill and Symons point out that centrally located facilities have economies of scale and lower marginal and operating costs and that when decentralization to smaller neighborhood facilities occurs, decentralization reduces travel costs by increasing accessibility. Since decentralization, however, also raises marginal and operating costs, there comes a point where these increases are so large that travel savings are more than offset and hence the spatial distribution of facilities is inefficient. That is, greater equity may be achieved by dispersing facilities and regulating the spacing of them but this incurs a reduction in efficiency. Efficient spatial distributions may also be equitable, but this requires that there be no spatial variation in income and/or density of population.

McAllister has done empirical work on the size and spacing of public facilities (recreation areas) and how this affects the trade-off between equity and efficiency. Service consumption, his measure of efficiency, is relatively insensitive to variations in size and spacing. Importantly, he notes the subjectivity of dealing with such trade-offs.[54]

Bigman and ReVelle provide another discussion of equity and efficiency, but their work lacks the clarity of Morrill and Symons' efforts.[55] They discuss the relationship between the provision of public services and the optimal location by employing a mathematical model based on concepts derived from traditional welfare economics. Several problems arise in their formulations. First, they implicitly assume that the services are provided in residential areas without explaining the spatial distribution of residential areas in the region under consideration (although one may possibly presume a central place arrangement in which a core urban place is surrounded by residential areas).[56] More importantly, they neglect to demonstrate why it is reasonable to suppose these services are located only in residential areas. Although they expand the problem formulation so that sites may be chosen from any point on the plane, this merely makes apparent that there will be some trade-off between the economies of scale of a few larger facilities and the provision of services in more numerous smaller facilities. Most importantly, the Bigman and ReVelle paper demonstrates that the optimal solution (in cost terms only) to the location-allocation problem may differ from the solution suggested by welfare economics. Their mathematical analysis shows, in symbolic form, the basic argument put forth by Morrill and Symons. This more rigorous treatment is a welcome addition to the literature. For Bigman and Revelle, efficiency is synonymous with the maximization of the social welfare function. It is important to note that selecting both different indifference curves for individuals and different isocost surfaces would change the results of their analysis; that is, the concentrated supply of services is not necessarily preferred to decentralized supply.[57] Finally, the authors recognize that income variations affect mobility and hence accessibility. While this may suggest that lower income regions should receive more facilities, it is not clear that these regions will succeed in acquiring more facilities in any bargaining process.

Orloff provides us with a model designed to replicate empirically observed evidence.[58] His work is a valuable contribution because it offers a model which incorporates both the desirability of living relatively close to a facility and the disbenefits of living too close to a service facility that has noxious characteristics. He does this by using a minimum standard of disbenefits to be endured for having the service available in a given proximity.[59] The model requires three sets of empirical data: 1)the location of neighborhood centers; 2) an index of political power using mean income as a surrogate; and 3) the locations of potential sites. Two behavioral assumptions are required: 1) for a noxious facility, more powerful neighborhoods or communities can tolerate greater access costs and force less powerful neighborhoods to bear high levels of noxious effects; and 2) with increasing power, communities can be more inflexible about the range of acceptable alternatives.[60] Orloff obtained fairly good results when he tested his model with hypothetical data as well as with empirical data on fire stations in Morristown, New Jersey. The model has the appeal of being sufficiently general to be applicable to a variety of facilities and being potentially useful as a planning tool because of its use of empirical observations. This work plainly shows the influence of Julian Wolpert.[61] Wolpert's interpretation of noxious facilities and the role of political power of communities in the bargaining process of facility siting are incorporated in Orloff's model. For example, Orloff notes that the likelihood of siting a noxious facility is enhanced in areas where such facilities already exist; he calls this the "dumping ground effect."[62] Despite Orloff's use of the Toregas model and simple surrogates for complex measures, his work should be placed in a distinctly different category than that of operations researchers because it emphasizes a concern for the political processes involved in siting facilities.

In another way, Andrew White goes beyond the sole consideration of accessibility in locational models for public facilities.[63] He adds a criterion of linkage or agglomeration in order to include a measure of locational interdependence. In this way, he recognizes that some types of public facilities have a propensity to be located closer to each other than is generally assumed. This is particularly true for more complex services, for example, health care, in which case nursing home care, mental health care and other ancillary services may occur near the hospital, the usual focal point of health care. The functional links among these services, or "interaction," include sharing staff and information, joint planning, coordination of services and patient referrals.[64] White examines empirical evidence for Philadelphia which illustrates his idea of locational interdependence. He suggests consideration of both the distance between linked services and the distance between consumers and service outlets. In order to test the role of accessibility in three study areas, he used nearest neighbor analysis and quadrant analysis based on an assumed uniform distribution of demand for several types of services. Results of these analyses support his contention that agglomeration tendencies deserve theoretical attention.[65] The empirical difficulty of measuring the often intangible linkages between services has not been overcome yet and some way must be found to measure or infer these linkages in order to carry out further analysis of locational interdependence. The major contribution that White makes is the identification of the role of "non-demand types of spatial interaction." This represents a significant improvement over previous models which have relied solely on accessibility measures.

Conclusions

This review of the public facility location theory literature reveals several deficiencies in the basic formulation of the theory. First, the work done to date lacks emphasis on the interdependence of systems. The work by Andrew White represents the first attempt to consider the important effects of other elements in the system on the spatial distribution of facilities. With this exception, the remainder of the literature seems to be at an early stage of development and unable to handle such complications, although they are critical to understanding the way in which public facilities are likely to be located in reality. Clearly this handicaps the use of this type of theory in the present work because attempting to understand the electric utility location problem in terms of the interdependence of the systems is one of the major foci of this dissertation. Furthermore, the present theories do not consider the effects of other institutions on the location of facilities. As White has demonstrated, this seems to be true of obviously related facilities (such as convalescent homes near hospitals) but it may also be true of other institutions which prima facie do not seem to be related to the primary focus of the location problem.

One aspect of institutional relationships that deserves explicit mention here is that of regulation. Regulation of both the siting process and of the price of electricity has in part determined the present locational pattern and will shape the future locational pattern of electrical facilities. The role of regulation, which is truly crucial in this location problem, has not heretofore been considered in the public facility location theory. Thus these deficiencies severely limit the usefulness of the theory, so it must be dismissed along with the other branches of location theory.

FOOTNOTES, CHAPTER TWO

1. Anthony J. Usibelli, "Electric Utilities and the Public-Private Ownership Debate," (unpublished paper, University of California, Berkeley, 1978), pp. 3-4.

2. For more information on the history of the electric utilities, see: John Bauer, Nathaniel Gold and Alfred Shaw, The Electric Power Industry: Development, Organization and Public Policies, (New York, Harper and Brothers, 1939); James E. Brittain, ed., Turning Points in American Electrical History, (New York, IEEE Press, 1977); and especially Harold C. Passer, The Electrical Manufacturers: 1875-1900; A Study in Competition, Entrepreneurship, Technical Change and Economic Growth, (Cambridge, Harvard University Press, 1953).

3. Usibelli, p. 15.

4. Charles M. Coleman, PG&E of California: The Centennial Story of the Pacific Gas and Electric Company 1852-1952, (New York, McGraw Hill Book Co., Inc., 1952), p. 320.

5. See for example, Richard Morgan, Tom Riesenburg and Michael Troutman, Taking Charge: A New Look at Public Power, Environmental Action Foundation, 1976.

6. J.H. von Thunen, The Isolated State, (Oxford, 1966).

7. Alfred Weber, On the Location of Industries, translated by C.J. Friedrich, (Chicago, University of Chicago Press, 1928); Edgar M. Hoover, Location of Economic Activity, (New York, McGraw Hill and Co., 1948); and Walter Isard, Location and Space-Economy, (New York, John Wiley and Sons and the MIT Press, 1956).

8. Walter Christaller, Central Places in Southern Germany, (Englewood Cliffs, N.J., Prentice-Hall, Inc., 1966).

9. See F.E. Ian Hamilton, "Models of Industrial Location," in: Socio-Economic Models in Geography, ed. by Richard J. Chorley and Peter Haggett (London, Methuen, 1968), pp. 361-424. Here the electric power industry is mentioned explicitly only once (p. 408) as being related to the industrial landscape of the bituminous coalfields. In addition, he notes in footnote 1, p. 408 that "public utilities" among other industries (not delineated) "are located along the waterfront."

10. Hamilton, pp. 372-374 and Hoover, p. 52.

11. Isard, 1956.

12. Coleman, p. 343.

13. California Public Utilities Commission, "Electric Service Areas, California," July 1979.

14. Geographers have placed the topic of electrical utilities in the context of industrial location, emphasizing minimizing production costs. See for example. Richard S. Thoman, The Geography of Economic Activity. (New York, McGraw Hill Book Co., Inc., 1962), p.257.

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26. Ross D. MacKinnon, "Dynamic Programming and Geographical Systems," Economic Geography, 46 (No. 2, Supplement, June 1970), p. 358.

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CHAPTER THREE: THE DECISION-MAKING ENVIRONMENT OF THE CALIFORNIA ELECTRICAL UTILITIES

Introduction

"The trouble with the world today is that the future is not what it used to be."[1] This succinctly summarizes the import of this chapter, devoted to describing the decision-making environment of the California electrical utilities. Uncertainty has always permeated the work environment of utility decision-makers, but the events of the 1960's and 1970's transformed the relatively stable, financially secure, expanding electric industry to one fraught with problems of a complex character and one where uncertainty looms as a greater difficulty than ever before. The electrical utilities are on a critical path in which the decisions of the next few years will determine, focus and direct their activities over the next several decades. This is not an entirely new situation, for any present state of affairs is undoubtedly the culmination of the "critical" decisions of previous decades; however, the difference now lies in the severity and often unexpected nature of the changes undergone by important elements in the decision-making environment. Alternately expressed, uncertainty always has been with the electrical utilities but it seems to be increasing in magnitude.

For a nation as dependent upon energy consumption as the United States, the recent events which have brought us to a "crisis" are dismal. While some of the crisis components may be easily identified--inflation, the environmental movement, regulation, fuel supply problems--the relationship among the components is not so easily set forth. Moreover, the survey process employed here to describe the decision-making environment of the electrical utilities becomes interwoven with the political views, values and biases of the participants in the decision-making process. For example, the academics studying the decision-making process are not objective observers of the process, but may themselves be fairly thought of as potential contributors to the decision-making process insofar as their "contributions to knowledge" can be put to use. It is impossible to even pretend that the survey presented here is "objective." However, it does represent an attempt at a balanced survey of the diverse views. Hence, both conservative sources, such as Public Utilities Fortnightly (from which the self-image of the electric utilities can be gleaned) and liberal sources are presented.

It is important to realize at the outset the limitation of such a survey. Neither economists nor any other group of experts seem to agree about many aspects of the energy situation in the U.S. at the present. Nor do they agree about what we can expect in the future. Perhaps the only matter upon which everyone concurs is that the economy has not behaved as expected. The economy has exhibited rising inflation simultaneously with rising unemployment. Furthermore, the complexity of the economy precludes prediction. Definition of the problems, and hence the solutions, are quite varied. Gaining an understanding of the decision-making environment, even though rudimentary, is a prerequisite, however, to couching the present research on the siting process and electrical system interdependence in the proper context. The changes of the past fifteen years have led to a remarkable alteration in the siting process for electrical generating and distribution facilities.

The electrical utilities in the U.S. prospered with the general expansion in the nation's economy at the close of World War II. The

1950's and early 60's can be characterized as the "golden age" for these electrical enterprises, especially the investor owned utilities, because the industry expanded with easy credit and little commotion or notice by the general public. Both long-term bonds and preferred stocks were bought by investors who thought this investment very safe. Utility stocks "were those in which widows should invest."[2]

Several factors contributed to the positive environment of the 1950's and early 60's. First, technological improvements and the economies of scale associated with larger generating units enabled the utilities to provide increasingly large amounts of electricity at a steadily declining cost per kilowatt hour. This led to a self-reinforcing growth cycle in which demand for electricity grew, new and more efficient plants were built to meet the demand, the cost per kilowatt hour declined, and more demand was thus encouraged. At the same time the introduction of new electrical appliances, including television sets, gave consumers more ways to use electricity. Growth in the electrical industry, largely viewed as positive, was directly correlated to growth in the general economy. In this situation,

> "growth in electric power supply could mean lower rates for all utility customers. At the same time, if equity capital could be raised at a cost below expected earnings levels, as was often the case, growth meant a large equity investment and higher earnings per share...with declining incremental costs, the utility's...customers and also its stockholders would be benefited by lower rates and higher company earnings."[3]

With this state of affairs, the utilities actively encouraged the use of electricity and promoted all electric homes. For example, according to PG&E Life, an internal publication for Pacific Gas and Electric Company (PG&E) employees, the promotional objectives of the PG&E home economics department were: "to sell gas and electricity...to aid appliance dealers and the industry generally by acquainting the public with the many new appliances coming on the market each year."[4] The women of the home economics department gave cooking demonstrations as well as electric range and other appliance demonstrations. In addition, their guest speaker service enabled many women's organizations to have a first hand experience with new products. The self-serving aspect of the home economists was a matter of company pride and ambition:

> "These, then, are our home economists--the group of women known individually as 'Miss' or 'Mrs. PG&E' to countless homemakers all over the system...That their work holds great potential is best shown by a recent study (which shows if) 10 percent of the 40 percent of our customers not now eating breakfast could be converted to do so, PG&E's revenue would increase by a quarter of a million dollars a year."[5]

This quote and the slogan "Live Better Electrically" aptly capture the spirit of the reinforcing growth cycle in the electrical utility industry.

A second factor was a general air of certainty of, or at least familiarity with, how to plan, build and operate generation and transmission facilities. Steady growth became a reliable rule of thumb and the technology used to meet demand, although continuously improving in efficiency, was well defined. Steam electric generation required either coal or natural gas (fuel oil only became more dominant in the 1960's) and hydroelectric generation became used increasingly.[6] For most utilities, nuclear power did not become an attractive technology until the mid sixties, after several early commercial reactors proved successful and apparently economical. So the choices available seemed clear, demand could be accurately predicted, and the return on investment was steady.

The most important factor in terms of siting was the fact that during this time regulation was concerned foremost with the rate structure, rather than the siting process. The California Public Utilities Commission (CPUC) generally restricted itself to occasionally reviewing a rate case and certifying that proposed power plants were needed. Given the self-reinforcing demand growth cycle, the task of demonstrating need was straightforward, and the electrical generating capacity during this period expanded rapidly.[7] The relative ease with which power plant sites could be selected, purchased, approved and built upon seems almost magical when compared to the more strictly regulated siting process that the California electrical utilities face today. Willrich suggests that an important element in the decision-making environment of the electrical utilities during this "golden age" was the political consensus which allowed the various interest groups to make their "tradeoffs."[8] This consensus, which disintegrated in the 1960's, rested mainly on a common attitude toward growth, confidence in technology, and trust in government and its ability to lead and to regulate.

Continued improvements in technology of all types gave the illusion that we could control and "fix" any problems we encountered by merely adopting the appropriate technology. Examples of this belief in technology abound. As a case in point, the nuclear industry aggressively pursed a commercial reactor program before "solving" the nuclear waste storage problem, because they were confident that the waste storage problem would be solved by the time nuclear wastes accumulated in quantities that were a nuisance. This belief is still held by present day nuclear power advocates, despite the accumulating evidence of the danger involved in all the methods proposed for nuclear waste disposal.

In the opinion of the State Energy Commission (SEC), no method of nuclear waste disposal has adequately been demonstrated, and hence the SEC will not approve nuclear power plant applications.

Inflation

What influences brought about the changes in this expanding, robust industry? First, the importance of inflation, which pervades the entire economy, cannot be underestimated in grasping the difficulties of the electrical utilities. In fact, the utilities view inflation as one of their most pressing problems.[9] Inflation, the real decline in the purchasing power of the dollar, has several effects on the utilities: distortion of price relations, expropriation of bondholders and shareholders, and problems for future financing. The distortion of price relations results from uneven adjustments throughout the economy, and concurrent changes in the prices of labor and capital.[10] The uncertainty this presents for estimating future costs is especially hard for the electrical utilities to cope with because their planning periods are so long. Decisions are being made presently for service that may be delivered fifteen to twenty years from now. Furthermore, because of the regulatory process which determines electricity rates and revenues, utilities are less able to respond quickly to changes in the economy. When an electrical utility requests a rate increase, several years may lapse before it is granted. By that time, inflationary pressures have raised the "real" costs of providing service, usually beyond the ability of present revenues to meet the costs.[11] The difficulty is exacerbated by having the rate increase, on the average, being only 50-60 percent of that requested.[12] The increases in costs, if due to fuel price increases, are often more quickly felt by the customer because of clauses in rate decisions that permit these costs to be passed on directly to the consumer. Thus, even with so-called "regulatory lag," between 1973 and 1979 the price of residential electricity has gone from 2.3¢ per kilowatt hour to 4.03¢.[13] Because electricity is more price elastic than the electrical utilities have anticipated, demand has dropped. The oil embargo of 1974 broke the historic 6-7 percent annual increase in demand, which presently is 3-4 percent in California. A circular pattern ensues which only aggravates the situation: the drop in the rate of increase in demand means that utility revenues do not increase in proportion to increase in costs (which continue to rise), the utility is faced with providing costlier service with insufficient revenues, rates usually go up and demand decreases further. (The drought in California produced a similar trap; the more water people conserved, the more expensive the water became.) Secondly, inflation inflicts losses on both bondholders and shareholders in the sense that their received returns decline in purchasing power.

The groups who suffer these inflationary losses are different for a "private" investor owned electrical utility and a "public" electrical utility. In the case of a government owned utility, the taxpayers provide the capital and carry the risks as well as the benefits, since they are the population being served. Because these groups (the risk takers and population served) are usually not the same people in the case of privately owned utilities, the willingness to bear the financial risk is distinctly lowered.[14] The utilities "have been described by Fortune magazine as an industry fighting for survival and by the Wall Street Journal as an industry with 'woes'."[15] This bleak picture should be tempered by some recognition of the conservative bias of the sources who decry the situation. Moreover, the negative prospects of reduced generating capacities will in part be softened by the reduced growth in demand. As the pressure mounts, relief probably will be sought in a variety of methods, such as deregulation of fuel pricing, changes in rate increase regulation and possibly government ownership of the utilities.

Capital for financing future construction projects becomes more difficult for the electric utilities to acquire because inflation accelerates the decline in their relative attractiveness as investments. Moreover, the utilities must bear the cost of present construction before new capacity plants may be added to the rate base. However, it is to be noted that there are two measures which have been used to permit utilities to recover some of the expenses during the years of plant construction. The first, "Construction Work in Progress" (CWIP), allows immediate return on construction expenses by permitting these costs to become part of the rate base.[16] According to Kahn, however, CWIP increases demand uncertainty by allowing more time for the long run price elasticity of demand to operate.[17] Because of political problems, CWIP has been used less frequently than the second measure, Allowance for Funds Used During Construction (AFUDC). In 1969, AFUDC represented 12.8 percent of the net income of the investor owned utilities but by 1978 this had grown to 39 percent.[18] This resulted in a reduction of both the market-to-book value ratio and the price earnings ratio of the utilities, and therefore caused them to appear distinctly less appealing for investment. Specific data on the financial status of PG&E demonstrate the trends discussed by Kahn (Table 3-1). The dramatic decrease in the percentage of market-to-book ratio

TABLE 3-1

Financial Status of the Pacific Gas and Electric Company[a]
1967 - 1977

I Market-to-Book Ratio of Stocks

	1967	1977
market price	$35.63	$24.00
book value	$20.62	$28.78
percentage	173%	83%[b]

II Percentage of Total Capitalization Represented in the Rate Base[c]

1967	1974	1977
92%	80%	76%

III Comparison of Authorized Allowance and Earned Returns

	1970-1977	1974-1977[d]
average authorized allowance on common equity	12.05%	12.35%
average return earned on equity capital	9.69%	9.28%

IV Percentage of Earnings Represented by "Allowance for Funds Used During Construction"[e]

1967	1974	1977
10%	27%	36%

Notes:
a) Kahn, Edward P., "Project Lead Times and Demand Uncertainty: Implications for Financial Risk of Electric Utilities," paper presented at E. F. Hutton Fixed Income Research Conference on Electric Utilities, March 8, 1979.
b) Presently, the market price is about 80% of book value.
c) figures are approximate
d) period of highest inflation
e) capitalization of the cost of construction capital

of stocks in ten years (90%) coupled with a decrease in the amount of capitalization in the rate base has adversely affected the earned returns of PG&E. Clearly, this present trend indicates that obtaining capital in the future will not be easy for the electrical utilities or for the energy industry as a whole:

> "The ability of (the energy) industry to obtain its share of the market is dependent on industry's attractiveness to the investing groups that compose that market. Capital will only be available to the extent that industry can offer it a satisfactory rate of return in the competitive marketplace. At the present time the federal government, and many state and local governments, are promoting policies, laws, and regulations that impede the ability of the energy industry to generate enough profits to be attractive in the capital markets. If this punitive attitude is maintained, the present stress in our energy structure will turn into an overwhelming crisis as industry strangles under the resulting curtailment of its supply capital."[19]

What can we infer from the rise in inflation about the siting decision-making process? The financial situation as described here suggests that capital will be hard to raise and so expenisve projects are less likely to be feasible. A current California example of this problem is the failure of the proposed Sundesert Nuclear power plant. Although the problem of nuclear waste storage was undoubtedly a key factor, the project was also very doubtful due to the complexities of financing such a venture. San Diego Gas and Electric (SDG&E), a major partner in the Sundesert venture, has lost $55 million dollars through investment in the plant,[20] which further reduces the utility's ability to consider other projects. The way to resolve this capital dilemma according to Kahn is to push for projects with smaller lead times and smaller capital investiments. Such a strategy is less risky and avoids the potential expense involved if too much generating capacity is built. Thus, one of the possible effects of this financial situation is that more and smaller plants will be proposed by the utilities.

In California, this will most likely lead to an increase in combined cycle projects, additions to capacity at existing sites, and the repowering of hydroelectric plants.

The Siting Process and Regulation in California

The Warren Alquist Act of 1974 established the California Energy Resources Conservation and Development Commission, now known as the California State Energy Commission (SEC). The SEC was charged with forecasting electricity demands and approving sites for thermal power plants. It was also made responsible for research and development of projects concerning alternative energy sources and for developing conservation measures and an emergency energy allocation program. The Commission was given the "exclusive power to certify all sites" and their certification is "in lieu of any permit, certificate or similar document required by any state, local or regional agency or federal agency to the extent permitted by law."[21] In particular, this altered the authority of the California Public Utilities Commission (CPUC) which had previously approved the need certificates for new power plants for private electric utilities. In addition, it brought the public electrical utilities which had not been under the CPUC under state regulatory control. Other permitting agenices at the state, regional and local levels lost their authority to hold their own hearings and issue permits. This consolidation of the permitting procedure into one agency, often called "one stop shopping," was perceived as one of the advantages of the SEC since it would help to reduce the time needed to approve the construction and operation of new generating units. The SEC's approval process consists of a two-part, three-year procedure involving a Notice of Intention (NOI) and an Application for Certification (AFC).

The NOI is an eighteen-month process intended "primarily to determine the suitability of the proposed site"[22] and to assure that the proposal meets the requirements of the SEC demand forecast, that is, need must be demonstrated in accordance with SEC forecasts. The proposal submitted by the utility must include a primary site, and three alternates of which at least one is not on the coast. Information also must be furnished on the expected environmental impacts. The NOI process affords the public a chance to participate in this planning process by attending the hearings and by intervening at those hearings if they so wish. The timetable for this process is detailed in Table 3-2.

The AFC stage involves seeking authorization for the construction and operation of power plants (Table 3-3). Although the utilities view the NOI process as aiming at the determination of site suitability and the AFC process as aiming at the determination of plant type suitability, the SEC actually closely examines both matters in each stage, thus blurring the distinctions between the two.[23] In the initial phase of the AFC, the SEC prepares an environmental impact report, which is completed within one year of the submission of the AFC. If conditions have changed in any significant way, the SEC may, within 180 days, reconsider the acceptability of the site approved in the NOI. Upon completion of the hearings and subject to the findings of the environmental impact report, the application is approved and construction may begin.

As part of the NOI process, the SEC is responsible for determining the "general conformity of the proposed sites and related facilities with standard(s) of the commission and (demand) forecasts."[24] Because

TABLE 3-2

Notice of Intent (NOI) Timetable[a]

Maximum Length for Event (days)	Event	Total Elapsed Time (days)
0	NOI submitted; includes design, economic, environmental features and need	0
30	Adequacy test; Commission judges completeness of the NOI	30
90	Time before public hearing on NOI	120
90	Length of public hearings on NOI	210
90	Time before Preliminary Report is issued; includes conformity with forecast, applicable laws, relative merit of each site, safety and reliability	300
60	Time for comments on Preliminary Report	360
60	Time before Final Report issued; includes conformity with forecast, existing laws, Coastal Commission findings, acceptability and relative merit of each site, any modifications ordered by Commission	420
60	End of hearings on Final Report (to commence within 30 days of the report and last no longer than 30 days - total of 60 days)	480
60	Time to decide NOI; based on Final Report and all the above proceedings	540

Notes:

a) Energy Analysis Program, Impacts of Future Coal Use in California, Interim Report, Lawrence Berkeley Laboratory, Berkeley, California, November, 1978, p. 59.

TABLE 3-3

Application for Certification (AFC) Timetable[a]

Maximum Length for Event (days)	Event	Total Elapsed Time (days)
0	Utility submits AFC based on an approved NOI	0
30	Commission judges adequacy of data submitted with AFC	30
variable	Hearings	180
180	Reconsideration of the NOI on which application is based. Application can be terminated in light of "current conditions" and "feasible alternatives."	180
365	Environmental Impact Report	365
	Decision on AFC; if approved, construction may begin	540 max. from day of submission; may be extended if Commission and utility agree.

Notes:
a) Energy Analysis Program, Impacts of Future Coal Use in California, Interim Report, Lawrence Berkeley Laboratory, Berkeley, California, November, 1978, p. 64.

"general conformity" has not been explicitly defined by the Warren-Alquist Act, the SEC has a great deal of latitude in deciding if the NOI is acceptable. It is anticipated that as more and more cases come before the SEC for approval that the criteria gradually will become explicit. These criteria already include a five- and 12-year electricity demand forecast, and the siting standards of the SEC. However, if the site is in the coastal zone (defined as any place within 1000 yards inland of the mean high tide line), the findings of the California Coastal Commission (CCC) also apply, as well as other current laws and regulations.

The SEC Biennial Report is a "comprehensive" document consisting of policy recommendation, an assessment of energy resources available to the state, and a formally adopted forecast of levels of demand for electricity for a period of 5, 12, and 20 years. Adoption occurs only after public hearings. These forecasts reflect the SEC's efforts to balance the requirements of growth and development, to protect public health and safety, to maintain (or improve) environmental quality, to consider the needs of the economy and to conserve natural resources. The 12-year forecast is used by the Commission to determine need for new generating facilities. Because these forecasts are not modified until the next Biennial Report is adopted by the SEC, the utilities can rely on the forecasts as a relatively stable element in their planning process.

Thus, instead of merely reacting to proposed utility resource plans based on company derived forecasts of demand, the SEC actively evaluates the proposals using their own forecasts as a basis for evaluation. In this important respect, the SEC is unique, although several states (New York, Ohio and Oregon) are contemplating instituting similar procedures.[25]

What methodologies are employed to forecast electricity demand? Conservation is one factor which can reduce the demand for electricity and thus augment the supply of electricity. Because the Commission has been explicitly mandated to evaluate the potential contribution of conservation to meeting California's electricity demands, that factor plays an important part in the formulation of its forecasts. The SEC relies primarily on a microeconomic end-use model to explicitly calculate the contribution of conservation, as well as load management and other consumption reducing measures to the lowering of the expected demand level. It is important to note that such consumption reducing measures are only used in this calculation and "shall not be considered as alternatives to a proposed facility during the siting process."[26] The end-use model calculates the total energy requirements by multiplying the number of electricity consuming devices and the amount of electricity used per device. This procedure requires estimating the consumption pattern of those devices which are not in constant use, for example, air conditioners and electric ranges. In addition, other consumer needs and preferences are estimated.

In contrast to the microeconomic approach of the SEC, the California electrical utilities employ macroeconomic methods to forecast demand. Such methods include the use of historical time series data and the regression analysis of variables such as the gross state product (GSP), income, previous sales and the price of electricity. Obviously, this type of analysis is based on the assumption that past relationships will hold for the future as well. In as much as uncertainty has increased since the Arab oil embargo of 1974, it has become less reasonable to make this assumption. The assumption, however, has persisted and this has led the utilities to consistently overestimate the demand for electricity. This overprediction averages 5.1 percent per year nationwide. Historically the demand for electricity exhibited a fairly constant six percent annual growth rate. Figures from the Edison Electric Institute indicate that between 1963 and 1973 electricity sales grew 6.6 percent annually while peak demand increased at a rate of 6.8 percent.[27] The currently lower growth rate can be attributed to the rising cost of fuel, lower population growth, saturation in certain appliance markets, conservation and increasing energy efficiency in industry. Furthermore, the historically validated relationship between the growth in gross national and state product and the growth in energy use seems to be falling apart in California. In the last three years, the gross state product and per capita income have risen twice as fast as the per unit growth of electricity. Finally, we can note that in 1978, the California GSP increased 7.8 percent after accounting for inflation. These figures are important for they bring into question the validity of continuing to use macroeconomic models based on relationships that clearly are changing.

The California Coastal Commission (CCC) plays a special role in the power plant siting process when any alternative proposed site or related facility is suggested within the coastal zone, for then the SEC transmits a copy of the NOI for the CCC to analyze. The CCC in turn presents its findings prior to the hearings held during the public review of the NOI. A similar procedure is set in motion when the proposed site is within those areas under the jurisdiction of the San

Francisco Bay Conservation and Development Commission (SFBCDC). Either of these agencies may request the assistance of the SEC in making their respective findings and may serve as interested parties in the adjudicatory hearings. No coastal site is approved as a primary site unless the SEC finds it has greater merit than the alternative sites.

In accordance with its enabling legislation, the CCC may designate certain areas within the coastal zone over which it retains its permit authority. This restricts the SEC to authorizing sites only if the CCC determines that the use is not inconsistent with the existing primary land use. For example, a new electrical generating facility would be a consistent land use in an industrial area or when a power plant has already been sited in a coastal area and an addition is planned. If the CCC determines that there will be no substantial adverse environmental effects and if the local public agency having ownership gives its approval, then other types of areas may be considered appropriate for siting.[28] During the AFC process, the CCC makes specific recommendations on the design characteristics of the proposed plant in order to reduce the plant's negative environmental impact. The SEC then must ascertain that the proposed facility will meet within "feasibility" these recommendations. However, "feasibility" has not been explicitly defined. Hence, the question of whether the SEC or the CCC has ultimate jurisdiction is open to jucidial interpretation. Furthermore, since the CCC may update its designated areas of authority every two years, they could conceivably remove authority from the SEC. Thus far, these jurisdictional questions have not been resolved.

The availability of cooling water makes the coast desirable for siting. The State Water Resources Control Board's policy discouraging the inland siting of power plants (so that fresh water may go to agricultural and other uses deemed as higher priorities) puts further pressure on the coast. Here again, the question of jurisdiction arises because these policies of the SWRCB and the CCC are in conflict with each other and the extent to which the SEC can resolve the conflicts is not clear.

Although the SEC is authorized by the Legislature to act as the primary agency in the power plant siting process, other state and local agencies still retain some authority in certain matters and the resolution of the resulting conflicts between these agencies has been gradually occurring. Formerly, the utility negotiated directly with each agency in order to obtain the necessary permits but now such interactions are handled through the SEC. PG&E's representatives feel that they have lost in this bargaining process because their personal contact networks cannot be utilized directly to PG&E's advantage. It does, however, seem that the utilities benefit from the fact that the SEC assumes the ultimate responsibility for such coordinating efforts. The Attorney General acknowledges the authority of the local governments: "the Legislature intends the Energy Commission to give great weight to the comments, opinions, ordinance and standards of local governments,"and local governments..."are not to be ignored or given secondary consideration..."[29] In order for a local ordinance to be overruled, the SEC would have to declare that no other "prudent and feasible means" of providing the needed electricity existed as an alternative to the proposed plant. If such a declaration is made by the SEC, then the certificate issued "shall supersede any applicable statute, ordinance or regulation of any state, local or regional agency in conflict therewith."[30] Only those agencies which own or control parks, wilderness, scenic, natural and wildlife reserves, or recreation or historic preservation areas (such as the State Lands Commission) have veto power in those areas over which they have jurisdiction. Only when the SEC chooses not to invoke its authority do the local and county agencies have de facto regulatory power in the permitting process.

The SEC is aware of jurisdictional interagency conflicts and is working toward fuller coordination of policies among the agencies. For example, the Air Resources Board (ARB) and the SEC adopted a joint protocol on January 23, 1979 to expedite the consideration of fossil fuel power plant applications. This protocol requires the air pollution control district (APCD) in question to report early in the siting process whether or not the air standards can be met by the proposed facility. In addition, the protocol reiterates the need for the utility to use the best available air pollution control technology. It also reaffirms the state energy commission's statutory power to overrule any state or local regulation that prohibits additions to the state's electrical generating capacity which have been deemed essential for continued supply. The Commission's interagency task force has examined coal waste disposal problems and has worked jointly with the California Coastal Commission on siting, and it has also sponsored air pollution control studies.

Overall, the SEC wants to establish a siting process that minimizes problems and expenses on both sides. In their 1979 biennial report they have outlined several ways to ensure an "open and fair process."[31] One way to do this is to have the Commission list and explain the major siting criteria which they use in determining the acceptability of a proposed facility and identify broad candidate siting areas in the state. To this end a constraint mapping study has been conducted, employing over sixty different factors considered as important siting criteria. By overlaying the maps of component criteria, composite maps for each technology have been obtained which clearly indicate the state's problem siting areas. The actions demonstrate the efforts of the Commission to be clear and open about the ways in which it deals with the utilities. Thus, the regulatory commission may be depicted as endeavoring to reduce the uncertainties and difficulties involved in the siting process.

Summary

In summary, it is important to note that the regulatory structure for siting, although designed to be fairly straightforward through the NOI and AFC processes, nevertheless represents a significantly more complex decision-making environment for the utilities than the one they enjoyed in the 1950's and 1960's. The outlook for the electrical utilities over the next decades does not promise relief but rather continued difficulties in several key respects. First, long lead times for the construction of power plants and transmission facilities will persist, especially as long as the utilities employ conventional large-scale generation technology. Only smaller-scale projects offer the prospect of shorter lead times.[32] Secondly, the number of "acceptable" sites for energy facilities can only grow smaller. Finally, the cost of electricity has continued to climb at a rate greater than the consumer price index, both because of higher costs of new construction and financing and because of the steady increase in the price of fuels.[33] These problems, combined with the regulatory atmosphere in the state, can only serve to encourage the utilities to take new directions in their planning strategies.

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7. Charles M. Coleman, PG&E of California: The Centennial Story the Pacific Gas and Electric Company 1852-1952, (New York, McGraw Hill Book Co., Inc., 1952), p. 334.

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14. See for example, "Why There Will Be a Money Crunch," Business Week, (no. 2587, May 28, 1979) pp. 111-124; C. Lowell Harriss, "Inflation: Its Significance for Public Utilities," Public Utilities Fortnightly, 99 (no. 5, March 3, 1977), pp. 17-23; Fergus J. McDiarmid, "The Rise and Decline of Electric Utility Credit," Public Utilities Fortnightly, 95 (no. 13, June 19, 1975), pp. 19-22; Edward P. Kahn, "Project Lead Times and Demand Uncertainty: Implications for Financial Risk of Electric Utilities," paper presented at E.F. Hutton Fixed Income Research Conference on Electric Utilities, March 8, 1979.

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18. Ibid., p. 7.

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CHAPTER FOUR: SYSTEM INTERDEPENDENCE AND SITING

Introduction

Electrical utilities began in the 1880's with the first successful installation of a generator occurring in California during 1887. Although most references cite the famed Pearl Street generation station in lower Manhattan, the Pacific Sierra generator had, in fact, preceded this station. From the outset, the electric utility industry flourished as many small firms served a multitude of municipal areas. However, gradually many of these firms consolidated their expanded and often overlapping service areas. A pattern of larger service areas served by fewer firms was established. This form of market organization, the "natural monopoly", was encouraged by extreme economies of scale: "The technical advantages of supply by one large firm are so commanding that a single firm is licensed by the government to serve the entire market."[1] In addition, the intensive capital requirements of the electric industry spurred this development, and today it remains the most capital intensive industry in the United States.[2] The technological developments which brought larger generating units and longer distance transmission required increasingly larger amounts of capital investment, thereby pushing small firms to consolidate so that financial resources could be more efficiently utilized. Furthermore, the expanded growth of electricity demand in large part aided the supply of capital. A reinforcing trend evolved in which the growing demand called for larger units to supply it and in which technological improvements not only made it feasible, but also dropped the unit cost of production, thereby lowering the price and encouraging even more demand.[3]

To illustrate, in 1901, the largest generators in use were 3 MW, but Samuel Insull of Chicago Edison spurred General Electric to develop a 5 MW generator, a feat accomplished in only seven months. The capacity of generators doubled (10 MW) within another eighteen months. It then rose to 32 MW in the next ten years and to 175 MW in the following decade.[4] This expansion in the size of the generating units dropped the price of electricity from 19.5 cents per kilowatt hour in 1898 to 5.28 cents in 1924.[5] At the same time, the number of firms who owned this capacity decreased. By 1914, 85 utility corporations owned 69 percent of the total installed generating capacity and of these, 35 controlled 50 percent.[6] As transmission technology improved, the physical interconnections among the utilities proliferated. The most important characteristics of the development of the electric utility industry at this time were the complex feedback relationship between technological improvements, the standardization of equipment, and the desire of the utility companies to employ their expensive capital investment as efficiently as possible. All of this led to an increase in the level of interconnection and coordination among the utilities.

While the development of extra high voltage transmission lines historically played a key role in the development of utility interconnections, the technology of computers has been a decisive factor in permitting the complex levels of coordination which exist today. In the early 1940's, utilities began to experiment with more frequent updating of the generation control setting (making finer adjustments to match more closely the level of generation to the level of demand at a given point in time). Analog control systems were developed to improve this control.[7] As computers became more sophisticated and available at "affordable" prices, it was possible for utilities to begin using this equipment to calculate expected load curves and to make other day-to-day computations, and eventually to permit direct control of the generating equipment by computer program. It is this level of computer use—instantaneous computer control of generation and transmission which is referred to as "central dispatch."

In the 1920's, the trend to interconnection was labelled "superpower," a term suggested by William S. Murray,[8] whose engineering research brought about the interconnection of Connecticut utilities in 1931. In 1918, the Connecticut Public Utilities Commission had already seen the potential for such an alliance. The Hartford Electric Company (Helco) executed a bilateral agreement with electric utilities in Massachusetts in 1922, thus cementing a union of the Connecticut and Massachusetts utilities, known as the Connecticut Valley Power Exchange. This was the first organized power pool in the nation and it was quickly followed by others, in particular by the Pennsylvania-New Jersey-Maryland Interconnection in 1927, which will be examined more closely below. In California, where a significant portion of the electricity supply relied on hydroelectricity, the severe droughts, especially that of 1924, provided further impetus for interconnection.[9] The basic motivations behind the trend toward interconnection long remained the same, for even in the 1950's and 1960's, coordination among electrical utilities was justified by the desire for "less likelihood of service interruptions, greater reliability, the introduction of more efficient generators, and the retirement of less efficient systems."[10]

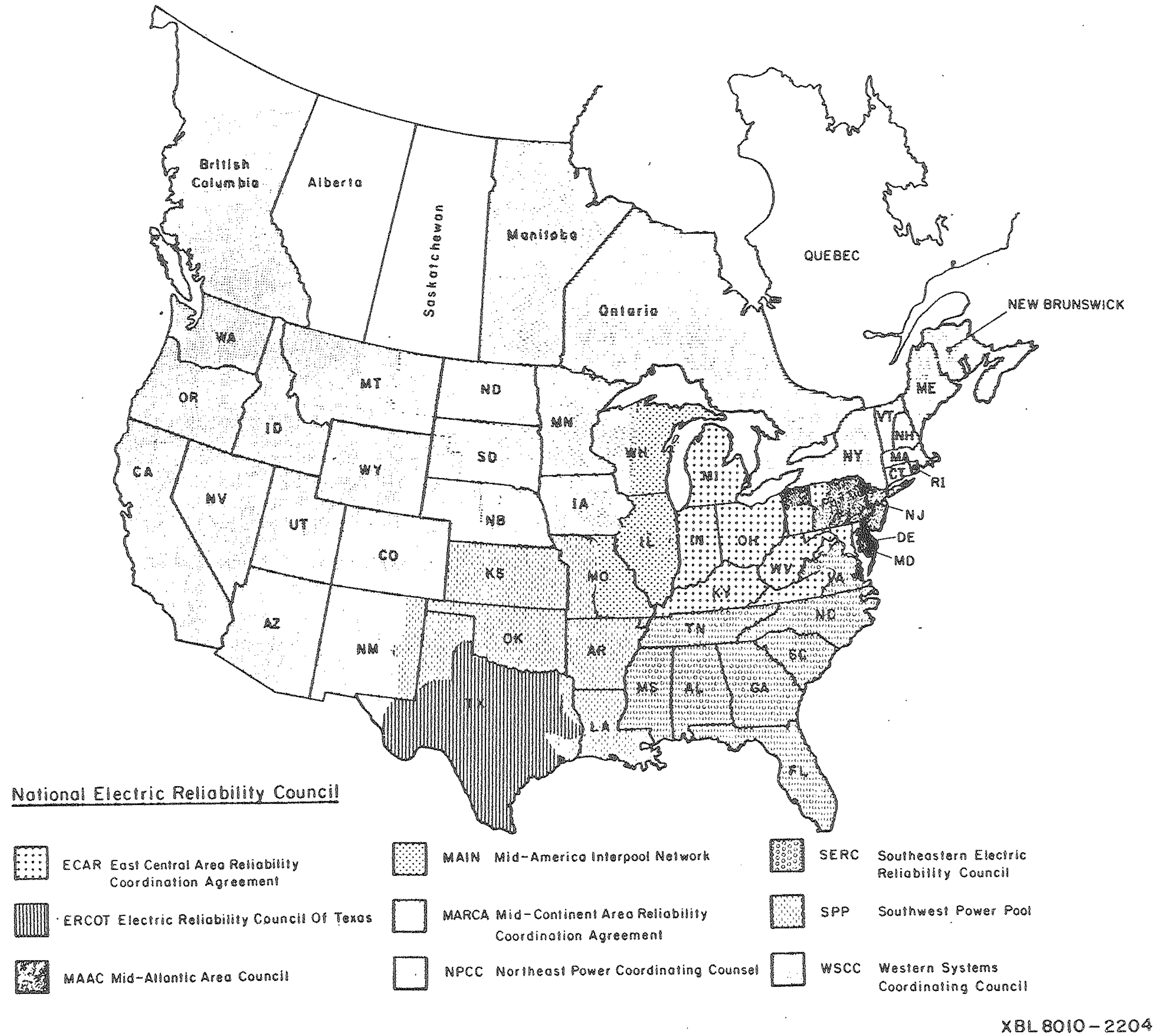
What are the specific advantages of power pooling? The main advantages have been summarized in Power Engineering.[11] 1) Utilities can derive economies of scale through common efforts. For example, if several utilities with a need for 150 MW each build a somewhat larger single unit instead of several 150 MW-sized units, the cost per kilowatt hour is reduced in the initial investment and the unit operating costs are also lower. 2) The reserve backup (spare generating capacity) is sufficiently large to permit larger generating units to be used with greater reliability of service. Basically, a utility operation in isolation from others cannot utilize very large single units because the disruption resulting from the failure of such units is too great to be tolerated. If, however, utilities are interconnected, they may rely on emergency service from elsewhere in the event of failure, thus minimizing disruption. Backup service thus permits the utilities to gain the economic benefits of lower production and maintenance costs associated with larger generating units while operating at an acceptable risk of failure level. 3) A large unit built for a pool is more likely to be used at maximum capacity factor[12] immediately, thus allowing capital investment to be recovered more quickly. 4) EHV (extra high voltage) transmission lines can be used, thus eliminating many small, low-voltage lines, because capacity is proportional to the square of the voltage. 5) Individual utilities can reduce their spinning reserve requirements because they can rely on the pool for emergency service. (Spinning reserve is reserve generating capacity available immediately from units that are ready to produce electricity and in synchronization with the system of already operating generators.) Thus the amount of reserve capacity owned by the utility can be lower and that amount of owned reserve capacity that is spinning can also be lower. (6) Investments in fixed capital may be made more timely by delaying expensive units until a more optimum time. Interim needs can be met through purchases of surplus available in the pool. 7) Maintenance schedules may be staggered, thus reducing the need for backup capacity and the use of less efficient standby units. 8) For systems with varying production costs, pooling permits sales and purchases of economy electricity. For example, utility A is better off to purchase electricity from utility B if B is able—at that given point in time—to generate the electricity from a less expensive resource. Utility A can then sell electricity back at a later time when it is able to produce more cheaply than B. Such "economy exchanges" also enable utilities to conserve their stock of expensive or hard-to-obtain fuel. 9) If peak loads vary seasonally among member systems, e.g., A peaks in June and B peaks in August, then a lower than otherwise possible total peak capacity can be developed to meet their respective loads during successive time periods. 10) Hourly "diversity exchanges"[13] are possible if daily peaks vary across areas (time zones often permit this). 11) Multiple transmission connections permit alternate routes for electricity flow, which increases system reliability. 12) Multiple transmission connections lessen the impact of fluctuating loads on a single generating unit.

The primary drawbacks to power pooling are the high cost of transmission lines and the cascading effect of a transmission loss. In addition, the limits to power pooling include scale problems. If too large an area is encompassed, the task of coordination becomes too complex; the number of people involved in decision-making at all levels (administrative, planning, and operation) becomes unwieldy. Similarly, the willingness of participants to submerge their self-interest to that of the pool varies with the size of the pool, and the financial integrity of the members. Finally, any similarity between the load curves of the participants limits the usefulness of a central dispatch since fewer economies of scale are derivable from the sharing of peaking capacity.[14] The extent to which the utilities in California perceive load curve similarity as a risk will affect the likelihood that their resistance to power pooling will be overcome. However, the barriers to an effective pooling agreement that are of particular importance to the power pool situation in California are of an institutional character. They are the only serious drawbacks because the high cost of transmission lines is more than offset by the savings from more efficient operation and the problem of blackouts can be solved by strengthening weak interconnections.

The formulation of electric reliability councils in the United States (Map 4-1) was directly prompted by the infamous power failure in the northeast which left 30,000,000 people without electricity on November 9, 1965.[15] This blackout ultimately resulted in a nationwide strengthening of ties among utilities and to the establishment of the National Electric Reliability Council (NERC) which serves as a central advisory body on electric reliability criteria. Previously, the only organization dealing with interconnections had been the North American Power Systems Interconnection Committee (NAPSIC), an informal and voluntary group which reorganized as an advisory group to NERC in 1978. It concerned itself with "frequency standards, time error standards and correction procedures, tie-line bias setting, deviation from tie-line schedules, actions in emergencies and reliability in general."[16] Clearly, proper handling of these group objectives required a more coordinated effort than could be provided by an informal group.

Interconnections

Electric utilities have a history of interconnecting with each other in


British Columbia
Alberta
Saskatchewan
Manitoba
Ontario
QUEBEC
NEW BRUNSWICK
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MD
National Electric Reliability Council
ECAR East Central Area Reliability Coordination Agreement
ERCOT Electric Reliability Council Of Texas
MAAC Mid-Atlantic Area Council
MAIN Mid-America Interpool Network
MARCA Mid-Continent Area Reliability Coordination Agreement
NPCC Northeast Power Coordinating Counsel
SERC Southeastern Electric Reliability Council
SPP Southwest Power Pool
WSCC Western Systems Coordinating Council
XBL 8010-2204

Map 4-1

order to increase system reliability and obtain the economic benefits derived from such interconnections. Although the degree of interconnectedness varies considerably in different areas of the country, generally the level of interconnection has increased over time. In fact, 97 percent of all electrical utilities in the United States are interrelated to some degree.[17] The interconnections range in complexity from simple low capacity ties between neighboring services areas to more commonly occurring high capacity ties. It is the high capacity ties which are necessary for sharing reserve margins, giving emergency support service and performing the economy energy exchanges which lower production costs and conserve fuel.

A more complex arrangement is the loosely tied power pool that involves more than two utility service areas. The Interconnected Systems Group (ISG) is one example of a voluntary power pool tied together with bilateral agreements, both written and unwritten. This pool, initially established in 1928, consists of 100 electric systems over a 32-state area (Map 4-2).[18] The California Power Pool Agreement (CPPA), a written agreement among the Pacific Gas and Electric Company, Southern California Edison, and San Diego Gas and Electric Company offers another example of this level of coordination. The most complex level is that of a "fully coordinated power pool" which is defined by Rincliffe as "a group of electric power systems, each under separate management or ownership, which are planned and operated under a formal pooling agreement designed to encourage the systems to obtain and share equitably the maximum benefits available from the pooling arrangement."[19] If operated as a single system, the large savings obtained may be divided among the contributing members. In order for a fully coordinated power pool to

THE INTERCONNECTED SYSTEMS GROUP

Source: R.G. Rincliffe, "Planning and Operation of a Large Power Pool," *IEEE Spectrum*, January 1967, p. 92

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Map 4-2

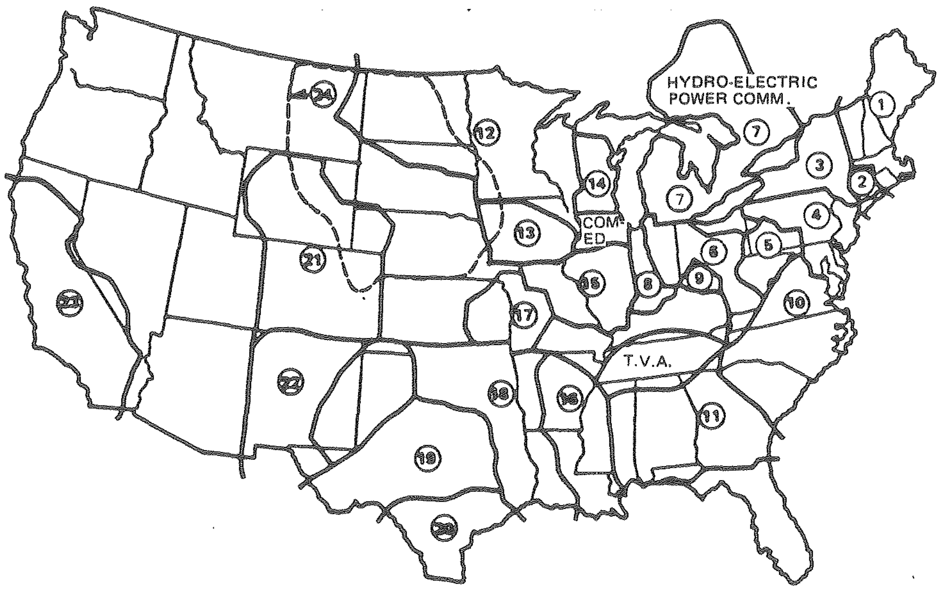
operate, three main requirements must be met. There must be: 1) high capacity intersystem ties; 2) a central dispatching headquarters; and 3) a functioning institutional arrangement of working committees, including an administrative committee, a planning committee, and an operating committee. The benefits to be gained are greater if there exist differences in the peak loads of the participants. If the peak loads of the member systems are coincident, then the installed capacity requirements will be about as great as if no pool existed. Furthermore, the slope of the load curves and diversity of possible forced outages will also affect the level of benefits to be obtained. The coordinated planning of capacity additions and maintenance scheduling can help reduce the amount of installed capacity.[20] It is also important to note the role of the central dispatching computer, because it is the continuous dispatching from a central headquarters that allows potential economic benefits to be more completely realized in the fully coordinated power pool than in a more loosely organized power pool. The central computer permits instantaneous computations that determine which resource in the system can produce electricity most efficiently and dispatches it accordingly.[21] In the more loosely coordinated power pools, these computations and the resulting schedules are drawn only hourly and dispatched by telephone. Presently, the daily operations of the Pacific Gas and Electric Co. are of the latter type.[22] Eventually, the savings gained by efficient continuous dispatching outweigh the cost of investment in the central dispatching computer and attendant facilities.

Pennsylvania-New Jersey-Maryland Interconnection

Before dealing with the particular situation in California, it is instructive to examine the history of other power pooling efforts in the

United States for it provides a basis for comparative analysis. The range of power pools in the U.S. is shown in Map 4-3, which specifically indicates the service areas of individual pools that together with other utilities are more loosely organized in the ISG illustrated in Map 4-2. One of the oldest power pools, the Pennsylvania-New Jersey Interconnection, was formed in 1927 by the consolidation of the Public Service Electric and Gas Company (New Jersey), the Philadelphia Electric Company and Pennsylvania Power and Light Company (areas 1, 2, and 5 respectively, Map 4-4).[23] Due to the addition of other companies over the intervening years, a revised agreement was formulated in 1956. This reorganized the pool, now the Pennsylvania-New Jersey-Maryland Interconnection, or PJM, to include Baltimore Gas and Electric Company (7), Pennsylvania Electric Company (9), Metropolitan Edison Company (10), New Jersey Power and Light Company (11), and Jersey Central Power and Light Company (12). A bilateral agreement between Baltimore Gas and Electric Company and Potomac Electric Power Company (8) allowed the latter to become associated with PJM in 1960, and join as a full member in March, 1965.[24] Presently, the Atlantic City Electric Company (3), the Delmarva Power and Light Company (4), and the Luzerne Electric Division of the United Gas Improvement Company (6) have individually contracted with various PJM members so that the effective working of the pool encompasses these firms as well. The organization of the PJM agreement is outlined in Table 4-1. The decisions of the management committee must be unanimous. The expenses of the Office of Interconnection are borne equally by member systems. Each member supplies all the generation and transmission equipment available that it controls in excess of its own requirements. Each member must provide a specific level of installed capacity calculated by a special PJM algorithm based on the

MAJOR POWER POOLS IN THE UNITED STATES



1. ECC Electric Coordinating Council of New England (1947)
2. CONVEX Connecticut Valley Power Exchange (1964) combination of Connecticut Electric Exchange and the Connecticut Valley Power Exchange (1922)
3. NYPP New York State Power Pool (1966)
4. PJM Pennsylvania-New Jersey-Maryland Interconnection (1927, 1956)
5. APS Allegheny Power System, Inc. (1925, 1960)
6. AEP American Electric Power Company (1958)
7. MICH-ONT Michigan Power Pool (1928, 1962) and the Hydro-Electric Power Commission
8. INDIANA Indianapolis Power and Light Company of Ontario (1966) and Public Service Company of Indiana and others (1964)
9. CCD Cincinnati Gas and Electric, Columbus and Southern Ohio, Dayton Power and Lift (1962)
10. CARVA Carolinas-Virginia Power Pool (1961)
11. Southern Southern Company (no date)
12. UMVPP Upper Mississippi Valley Power Pool
13. IOWA Iowa Power Pool (1958)
14. WPS-WPL Wisconsin Public Service Corporation — Wisconsin Power and Light Company Pool (1960)
15. ILL-MO Illinois-Missouri Pool (1952)
16. MSU Middle South Utilities
17. MOKAN Missouri-Kansas Power Pool (1962, 1965)
18. SCEC South Central Electric Companies (1964)
19. N. TEX. I.S. North Texas Interconnected System
20. S. TEX. I.S. South Texas Interconnected System (1942)
21. Rocky MT. Rocky Mountain Power Pool include Colorado Power Pool (1956)
22. NEW MEX. New Mexico Power Pool (1941, 1951)
23. CALIF California Power Pool (1964)
24. MBSG Missouri Basin Systems Group

Source: "Status of Power Pools, Part 2," *Power Engineering*, 71 (no. 6, June 1967), p. 59. NB. The degree of coordination among these pools ranges from informal to a single operating system with central dispatch. Also, not every utility within a designated area necessarily belongs to the pool.

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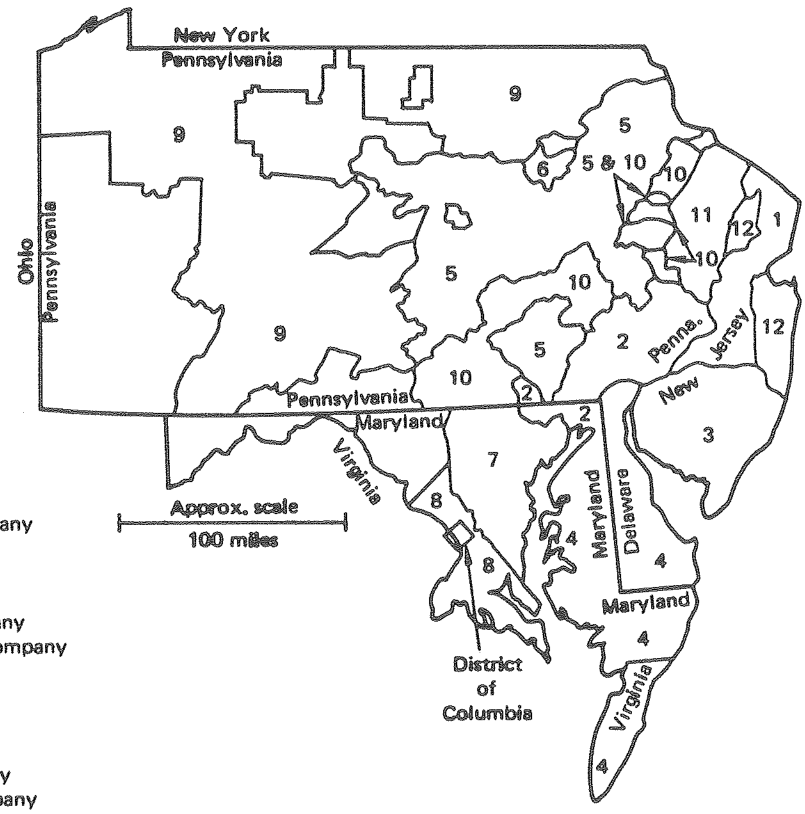
Map 4-3

THE PENNSYLVANIA-NEW JERSEY-
MARYLAND INTERCONNECTION



The Pennsylvania-New Jersey-
Maryland Interconnection

1. Public Service Electric & Gas Company
2. Philadelphia Electric Company
3. Atlantic City Electric Company
4. Delaware Power & Light Company
5. Pennsylvania Power & Light Company
6. Luzerne Electric Division — UGI Company
7. Baltimore Gas & Electric Company
8. Potomac Electric Power Company
9. Pennsylvania Electric Company
10. Metropolitan Edison Company
11. New Jersey Power & Light Company
12. Jersey Central Power & Light Company

Source: R.G. Rincliffe, "Planning and Operation of a Large Power Pool," *IEEE Spectrum*, January 1967, p. 94

XBL809-1947

Map 4-4

Table 4-1

Pennsylvania-New Jersey-Maryland Interconnection Organization Chart

Management Committee (unanimous decisions)	Office of the Interconnection	Operating Committee (Majority Vote)	Maintenance Committee	Planning and Engineering Committee
One corporate officer from each member system: policy formulation.	Manager: a) schedule sufficient operating capacity to cover the peak load with sufficient reserve to avoid forced outages; b) personnel management; c) negotiations with other power pools and neighboring systems. Dispatchers: a) instantaneous checks of operating reserves; b) schedules hourly exchanges with neighbors. Engineers: a) monitor the automatic load-frequency control equipment; b) accounting for transactions; c) development and maintenance of operating and accounting computer programs. Load Schedulers: a) obtain daily peak load estimates and minimum requirements; b) estimate peak for the period and operating reserves; c) schedule additional units as necessary.	Representatives from each member system: establish operating and accounting procedures.	Representatives from each member system: coordinates the scheduling of maintenance work on all PJM generating units.	a) coordinates planning and engineering of major interconnection facilities; b) system studies (on a pool basis); c) coordinates with other pools planning.

Source: R.G. Rincliffe, "Planning and Operation of a Large Power Pool," IEEE Spectrum, January 1967, pp. 94-95.

annual peak load and an average requirement determined by seasonal load. Those members having an insufficient installed capacity may in theory reap savings from lower carrying charges and operating expenses. If such savings actually materialize, they are passed on to those members who supply excess installed capacity. The savings of supplying and receiving systems are equally shared, in that they are allocated in proportion to the members' respective contributions to the overall system. The pool's distinctive feature is its central dispatching office which handles all operations and accounting for the internal flows, as well as the regulation of flows from PJM to neighboring power pools in New York, Ohio, Maryland, and Virginia.

An important feature of the PJM pool is the joint projects which are planned and executed by member systems. For example, two coal-fired mine mouth generating units (each 900 MW) have been built in western Pennsylvania, the Keystone Station, and the Conemaugh Station. The Keystone Station is owned as tenants-in-common by seven members who hold varying percentages of the total capacity. Similarly, the Conemaugh Station is owned by nine members.[25] These jointly-owned generating units have necessitated the building of a jointly-owned 500KV transmission line for carrying the electricity to the load center.

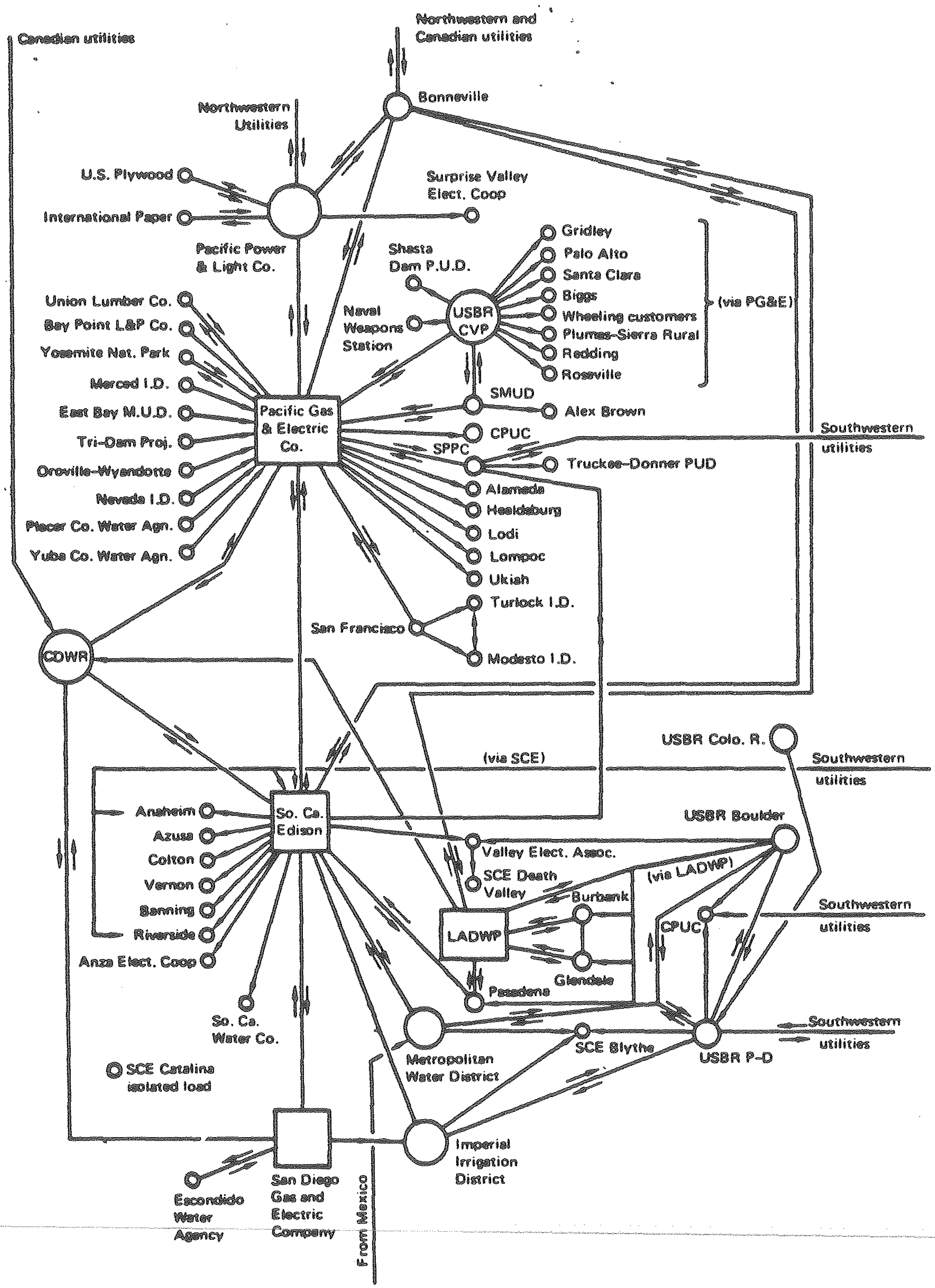
The PJM pool serves as an important model and precedent in demonstrating the benefits of a fully coordinated power pool for supplying electricity as efficiently and reliably as possible. Its longevity and accommodation of both membership growth and increased generating capacity suggests that this type of institutional arrangement could provide similar viable, flexible, and beneficial results for electrical utilities and their customers in other regions of the United States.

California

In Chapter One, the present day trends in energy use and electricity in the state were discussed and the spatial distribution of power plants and transmission lines was presented. Now we will focus on the service areas of the utilities in the state (Map 2-1) and on the system interdependence which has been established among the utilities. System interdependence is exhibited in both the physical and institutional arrangements among the utilities. The physical relationships are schematically presented (Figure 4-1). The primary institutional relationship to be examined here is the California Power Pool Agreement (CPPA).

The majority of the pools in the U.S. were formed during the 1950's and 1960's, in parallel with the general boom growth period experienced by the electric utility industry during that same time period. In California, discussion of such a power pool began in the mid-1950's. It required several years of negotiations and draftings to formulate the initial agreement. On December 14, 1961, Pacific Gas and Electric Company (PG&E), Southern California Edison (SCE), San Diego Gas and Electric Company (SDG&E), and the California Electric Power Company (CEPC) signed this initial agreement. Later, CEPC merged with SCE and the power pool agreement was amended and became effective on July 20, 1964. The agreement specifies the contractual terms under which the pool operates among the "area systems" of the member utilities. The "area system" of a "party" (member utility) consists of:

> "its system together with (a) each other system of a third party with which it normally operates in parallel by means of facilities and under agreements which result in effectively integrating their loads and resources from an operating standpoint, and (b) generating plants in California, not included above, substantially all the output of which is sold to the party and integrated into the party's system."[26]



Interconnection of California Utilities

Fig. 4-1

Part (a) of this definition provides for the contracts that PG&E and the other members have with third parties who are, on a day-to-day basis, integrated into the operation of the specified utility. In particular, it is through this arrangement that LADWP becomes a de facto member of the pool agreement. Any such third party thus receives indirectly the benefits of the pool obtained by the member utility with which they have contracts. Often, this is a major advantage for the third party. For example, in the SMUD/PG&E agreement, PG&E provides back-up service which is especially advantageous for SMUD during the summer when its own electrical supply is limited and peak demand is high in the Central Valley.[27]

To be specific, the area system of PG&E consists of: the PG&E system, the system of the Central Valley Project (excluding Project pumping), the Sacramento Municipal Utility District, the City and County of San Francisco, the generating plants of the East Bay Municipal District, the Merced Irrigation District, the Oroville-Wyandotte Irrigation District, the Tri-Dam project of the Oakdale and South Joaquin (sic) Irrigation Districts, the Placer County Water Agency, and the Yuba County Water Agency.[28] The area systems of SCE and SDG&E are simple by comparison, for the area system of SCE consists of its own system plus that of the Metropolitan Water District while that of SDG&E is synonymous with its own system.

Several aspects of the California Power Pool Agreement deserve mention. First, the types of services which it stipulates are summarized briefly in Table 4-2, although certain exceptions to these terms have been specified in the agreement. The most frequently used services are "economy capacity," "economy energy," and "short-term firm service." Second, the organization of the pool differs markedly from that of PJM

Table 4-2

Service Provisions of the California Power Pool Agreement[a]

1) Short Term Firm Service

- Provisions

By mutual agreement, furnish energy for period of up to 45 days, subject to renewal. Supplier excludes such capacity from Capacity Resources and receiver includes such capacity.

2) Emergency Service

If stressed party is using all of its spinning reserves,[b] may receive as much spinning reserve as stressed party is required to maintain from the others, for period of up to 2 hours. Energy must be returned but there is no charge if received for less than 2 hours and entitlement not exceeded after first half hour. May receive energy for up to 60 days if emergency continues and stressed party uses due diligence.

3) Economy Capacity Service

By mutual agreement, furnish energy on condition it may be discontinued with no more than 24 hours notice but with sufficient notice to allow receiver to provide alternative service. Supplier excludes such capacity from Capacity Resources and receiver includes such capacity.

4) Economy Energy Service

By mutual agreement, furnish energy on condition it may be discontinued without notice.

5) Capacity Resources Standby Service

In the event of capacity resource deficiency, if stressed parties resources are fully used, may receive energy for up to 7 days to supply firm load. May be renewed.

6) Energy Exchange Service

SCE may serve as intermediate system between the supplier and receiver.

Notes:

a) H.R. Perry, "California Power Pool Description," unpublished document, Pacific Gas and Electric Company, San Francisco, California, November 1979, pp. 2-3.

b) Spinning reserve requirement equals at least 7 percent of daily peak demand.

c) Capacity resources deficiency occurs if available capacity resources are less than 110 percent of peak load (capacity resource requirement).

(Table 4-3). Only one standing committee (an Engineering and Operating Committee) is established by the agreement, compared with the four committees of PJM. PG&E views this combination of planning and operating functions as important for the smooth operation of the pool because it means that the communication between representatives of member utilities is better than in pools where those functions are handled separately. The planning members prepare their load and resource reports based on information received directly from the operations office and together they formulate their recommendations to the Board of Control.[29] It is surprising that there are fewer committees provided for by the CPPA because by definition it is a much more informal institutional arrangement and does not need to manage central dispatch functions. Although PG&E suggests that the communications gap has been narrowed by such a combined committee,[30] it is questionable that communications of a committee which meets so infrequently are as effective as they imply. Their communications clearly are sufficiently effective for the system to actually operate, but they may not be as efficient as PG&E suggests. Finally, the scheduling of maintenance for transmission lines requires 72 hours notice when any major equipment outage is to be involved and the schedule of maintenance for generation equipment, which is fairly predictable, is updated once a month.

Selection of PG&E

Within the state of California, several different types of public and private organizations provide electricity. Specifically, the public organizations include special agencies, such as the Department of Water Resources and various irrigation districts (Imperial, Modesto, and Turlock Irrigation Districts being the three largest); municipal utilities, both

Table 4-3

California Power Pool Organization Chart[a]

Board of Control	Engineering and Operating Committee	
Meets on call of chair, approximately every 1½ months. Review, coordinate and approve member's programs for provision of resources.	Responsible to board; meets approximately 1½ to 2 month intervals. Monitor activities; make recommendations to Board of Control. Functions as working Committee of Board. Membership: Chief planners and operating managers heading power supply activities. Planners: technical studies of capability of transmission ties. Operators: report on actual daily operation experience to improve planning.	No formal independent planning commission.

Notes:

a) H.R. Perry, "California Power Pool Description," unpublished document, Pacific Gas and Electric Company, San Francisco, California, November 1979, pp. 4-5.

large scale (Sacramento Municipal Utility district and LADWP) and small scale (Alameda, Anaheim, Riverside, and others); as well as cooperative organizations, (Mountain Empire Electric Cooperative, Valley Electric Power Association Cooperative, Inc.) (Table 4-4). Measured in terms of number of customers served and the kilowatts of electricity consumed, the major utilities are PG&E, SCE, SDG&E, LADWP, and SMUD. Many of the municipalities act solely as distributors of electricity which is bought wholesale from a large utility, that is, they own no generating capacity. Others produce electricity which is in excess of their own requirements and sell this surplus to a utility (for example, Bay Point Light and Power or the Union Lumber Company).

In order to study the implications of interconnection for siting, it is necessary to examine those organizations who not only own and operate both generating and distribution facilities, but also are of sufficient size to have a noticeable effect on the spatial distribution of electrical facilities. Only the major utilities meet this requirement. Of the major utilities, PG&E is the largest in service area covered, the number of customers served, and generating capacity (Table 4-5). Furthermore, PG&E integrates more numerous and diverse smaller organizations within its own system than any other California utility. Thus, within its own service area there already exists a complex interconnected system (Figure 4-1).

The selection of PG&E for the closer study of power pooling is also justified because of its prominence nationwide. PG&E is the largest electrical utility in the United States.[30a] Another reason of no small consequence is the convenience of studying a nearby utility.

Table 4-4

California Electrical Utility Organizations[a]

Investor-Owned Utilities (7)	Municipal Systems (23)	Irrigation Districts (6)	Rural Electric Cooperatives (5)	United States Government (3)	Public Power District (1)	State-Owned System (1)	County Systems (2)
California - Pacific Utilities Company Pacific Gas and Electric Company Pacific Power and Light Company San Diego Gas and Electric Company Southern California Water Company Alex Brown Company Bay Point Light & Power	Alameda Anaheim Azusa Banning Biggs Burbank Colton Glendale Gridley Healdsburg Hetch Hetchy (San Francisco) Lodi Lompoc Los Angeles Palo Alto Pasadena Redding Riverside Roseville Sacramento Santa Clara Ukia Vernon East Bay Municipal Utility District Escondido Water Agency	Imperial Merced Modesto Oroville-Wyandotte Turlock Oakdale and San Joaquin	Anza Electric Cooperative, Inc. Southern California Edison Company Plumas-Sierra Rural Electric Cooperatives Surprise Valley Electrification Corporation Mountain Empire Cooperative Valley Electric	National Park Service (Yosemite) Bureau of Reclamation, Department of the Interior Shasta Dam Area Public Utility District	Truckee-Donner Public Utility District	California Department of Water Resources	Placer County Water Agency Yuba County Water Agency

Notes:

a) Electrical World Directory of Electric Utilities 1977-1978, (New York, McGraw-Hill, Inc., 1977), pp. 77-99.

Table 4-5

Descriptive Statistics of Major California Electric Utilities[a]

Utility	Electricity Customers		Total Generating Capacity[d]	1976 Sales of of Electricity
PG&E[b]	residential	2,670,797	10,680,900 kw	61,134,245,970 kwhr
	commercial	310,554	14,424,300kw[e]	
	agricultural	90,841		
	industrial	792		
	others	14,316		
	total	3,087,300		
SCE[b]	residential	2,497,076	14,065,748 kw	53,685,378,000 kwhr
	commercial	227,143		
	agricultural	25,465		
	industrial	31,405		
	others	33,314		
	total	2,814,403		
SDG&E[b]	residential	579,968	2,104,000 kw	8,440,097,766 kwhr
	commercial	57,477		
	power	7,212		
	others	760		
	total	645,417		
LADWP[c]	residential	972,087	-	17,128,170,123 kwhr
	commercial	127,272		
	industrial	18,723		
	others	5,498		
	total	1,123,580		
SMUD[c]	residential	251,738	1,566,000 kw	6,342,115,000 kwhr
	commercial & industrial (sm.)	23,006		
	commercial & industrial (lr.)	4,320		
	others	3,557		
	total	282,621		

Notes to Table 4-5:

a) Source: Electrical World Directory of Electric Utilities, 1977-1978, (New York, McGraw-Hill, Inc., 1977), pp. 77-99.

b) Member of California Power Pool.

c) Municipally owned system.

d) Generation capacity as of January 1, 1977.

e) Total system capability.

My research was facilitated by using established personal contacts between the staff scientists at the Lawrence Berkeley Laboratory and the staff at PG&E. PG&E's familiarity with the University of California also eased the difficult task of obtaining information. Unfortunately, as is often the case in doctoral research, time and monetary constraints precluded consideration of a wider range of data sources, such as the information which could have been gathered by personally interviewing staff members of other utilities. The interviews are discussed more fully in Appendix I.

Day-to-Day Operation of PG&E

The ways in which the utilities communicate with each about their daily and longer-term planning and operation represents one measure of the degree of their interrelatedness. We have already briefly mentioned how the hourly communication of some power pools directs their flow of electricity and how the second-by-second control and communication of a centrally dispatched pool performs the same function.

In the PG&E system, the office of the manager of power control serves as the operations office responsible for the production and transmission of the electricity necessary to meet demand in the system. The office's primary goal is to meet demand while maintaining an appropriate level of frequency (60 hertz), and then to produce the next increment of power at the lowest possible cost.[31] On a daily basis, the company meteorologist files a weather report at about 5:00 p.m. outlining the expected weather for the following day. This provides part of the input data used in a computer programmed model for calculating the expected load throughout the next 24-hour day. The model is based on 20 years of historical load and weather information for the system.[32] These calculations are performed for four critical points in the PG&E system. Given these expected loads, the generation equipment necessary to meet such a load is prepared. This would include the baseload generation equipment already producing power plus any additional peaking capacity needed on a stand-by basis. Then throughout the day, hourly communications take place by telephone between dispatchers at PG&E and other dispatchers in the pool and at LADWP. The dispatchers compare the marginal costs of production so that the electricity used in the following hour is the most cost-effective. This process has been described as "central dispatch by communication."[33]

The manager of power control at PG&E can contact his counterpart at the other utilities by flicking a switch on his telephone. Any information which he communicates this way is usually confirmed in writing. Finally, PG&E also makes hourly reports to the Western Systems Coordinating Council (WSCC), headquartered in Salt Lake City. These reports cover PG&E's load and how they are meeting it. If an emergency arises, power is obtained from other pool members or through other contractual arrangements, such as those with the Bonneville Power Administration. To illustrate, when on November 25, 1979 at approximately 3:56 a.m., the Rancho Seco Nuclear power plant developed a leak in a valve and shut down, PG&E was able to arrange for the purchase of 520 MW from SCE to replace the lost generation.[34] Such arrangements begin with a simple telephone call, the most fundamental action necessary for obtaining the electricity. This is followed by calls to the legal department to formalize the spoken agreement--usually in a two- to three-page letter of agreement. The PG&E legal department checks with the PUC and also the Federal Energy Regulatory Commission (FERC) when the transaction fails under federal jurisdiction as it does when interstate transfers (such as those from the Bonneville Power Administration) take place. Finally, the office of power control contacts the economic and statistics division to report on the transaction.

Central Dispatch in California

Since the day-to-day operations of PG&E and the other California utilities rests on hourly dispatching communications, the next possible step in the interconnection of the utilities in California would be to reconstitute the CPP and LADWP into a more closely-knit structure with a central dispatching office. It is necessary to evaluate the prospects for this occurring and to examine what the actors involved think because such a change in their operations ultimately will have some impact on the siting decision-making process for future electrical generation and transmission facilities. First we will examine the position of PG&E and then that of the SEC.

The official position of PG&E regarding the possibility of investing in a centrally dispatched electric system is that such an investment is not warranted at the present time.[35] The reasoning of PG&E's management is based on their perception of the costs and benefits. To them, the benefits include being able to reduce the cost of providing electricity to their customers and being able to increase system reliability. They regard the most substantial costs as those resulting from substantial investment in personnel and equipment, and from loss of decision-making autonomy in important investment and siting decisions. Furthermore, PG&E places great emphasis on their responsibility to make a "fair return" on their stockholders' investment. And, because they perceive the investment in a central dispatch system to be of questionable profit for themselves, they suspect such an investment at this time could jeopardize their financial solvency and possibly their ability to raise capital.

According to the manager of power control, the situation in California is more similar to that in the New England Power Exchange (NEPEX) than, for instance, PJM.[36] He runs his office with 42 people, which includes production, technical and clerical staff, whereas the central dispatch office of NEPEX has 65 people. When comparing these figures it should be realized that the service area of PG&E is slightly larger than all of the NEPEX service area and that the PG&E load is slightly larger than the NEPEX load. The staff of the NEPEX central office represents an addition to overall pool staffing requirements because each of the NEPEX member utilities has to maintain their own production staff. Thus, it is argued, a central dispatch office would not obviate the need for any of the staff presently employed by PG&E in its office of power control.[37] That is, the cost of new personnel would not be offset by reductions in present staffing. The manager of power control estimates that the establishment of the central dispatch office with its computer equipment would cost between 15 and 20 million dollars. Given the present efficiency of the PG&E system, he does not think it is a justifiable expense.

In addition, the vice president of transmission planning stated that the service area which would be included in such an integrated power pool was so large that, in order to sensibly allocate generation to meet demand, it would have to be divided up into smaller sub-areas to facilitate more manageable calculations. Hence, the present pattern of areas approximates the optimum that a larger pool could offer because the PG&E service area itself acts as a large, integrated pool. The same vice president declared the following in a document on the CPPA:

> "The California Power Pool Companies have not seen fit (sic) in establishing a centralized dispatch. The Board has examined this situation from time to time, as they observed centralization and regional control being adopted in other regions of the country. To date, it has concluded that the situation in California does not, at least at this time, warrant a more centralized operation. Its conclusions are that the sought after benefits of centralization are achieved now under the existing California Power Pool Agreement with independent control areas and control centers. In some regions of the country the utilities involved in a pooling arrangement believed it was in their best interest to relinquish some of their prerogatives and assign them to another level of hierarchy. However, in view of the fact that within the PG&E control area there are a number of irrigation districts, a state project, a federal project, and municipal and district projects which are integrated into the operation, it should be apparent that the PG&E power control group performs not only the function of centralized control for a large electric utility, but it also performs many of the functions that typically get assigned to a pool dispatching office. By way of comparison, the PG&E control area geographically and in terms of load is approximately equal to that of New England. Much the same could be said of the Southern California Edison Company system and its dispatch organization. Since the arrangement can be managed efficiently and since the record of reliability continues to be good, they question the motivation of adding operation hierarchy and duplication of both personnel and technical facilities where they see that additional burdens would be placed on the utilities without the gains to be achieved being evident."[38]

His statement about other utilities being willing "to relinquish some of their prerogatives" indicates that PG&E does not wish to lose control over its daily operation and investment decisions. In a fully integrated pool, the needs of the entire pool are the first consideration and individual utilities must work for the common good—a goal which may not always coincide with their self interests. Given California's important regional differences in the distribution of water resources and other phenomena, it seems likely that there would be many conflicts between the utilities due to differing self interests. Furthermore, PG&E regards it as unfair to lose control over its resources if this means depriving the shareholders of "just" returns.[39] For example, if demand and supply are considered on a statewide basis and it is most efficient to meet demand in southern California with PG&E-owned hydroelectric capacity, then PG&E would view that transaction as detrimental to their stockholders because the benefits of employing a relatively cheap source of electricity are going elsewhere. After all, the argument goes, the PG&E stockholders were willing to put up the money and thus should reap the benefits.[40] Put otherwise, the members of the pool differ in their respective financial strength and PG&E is financially more profitable and stable than SDG&E and consequently views central dispatch as a dilution of their financial integrity. Or more bluntly stated, "Why should we subsidize SDG&E's bad management?"[41] This attitude illustrates the important difference between public and private ownership; for such an argument clearly would not be put forth by LADWP. The staff interviewed at PG&E emphasized that it is a fundamental concern of PG&E to insure a solid rate of return on their stockholders' investment. The stress this point received is not unexpected, given the company's opportunity to make a public statement as they did in the course of the interviews. It is obviously company policy to show that the stockholders' investment is of the utmost importance and it is in their own best interests to do so. In my estimation, this concern of PG&E's serves as a major obstacle against the adoption of a central dispatching office, although it is unclear from the interviews how directly this attitude will affect the course of negotiations among the utilities as they continue to explore such a possibility.

PG&E has several joint projects with SCE, SDG&E, and LADWP to pursue the possibility of increased integration. First, there is a California Increased Integration Group which has been in operation for about a year and a half and consists of planners from the respective utilities who are exploring answers to the following questions. Are there additional benefits to be gained from the present interconnections? What are the prospects for further integration? If so, what are the costs and benefits thereof?[42] The formation of this group was prompted by the dissatisfaction the participating utilities had with a study concerning increased integration carried out by Systems Control, Inc. with SEC funds. PG&E felt the study was "atrocious"[43] and joined with the other utilities in "self defense." Secondly, through a contract let by SCE to the EMA Corporation in Georgia, PG&E, SCE, SDG&E, and LADWP are funding research for a study comparable in scope to the SEC's. They expect it to demonstrate a more "reasonable" representation of the situation. This study was not yet available for public perusal at the time this dissertation was written.

LADWP represents a special case partly because it is not a member of the CPP although it is one of the state's major utilities and partly because it is a public utility. It would simply be impossible for the CPP to operate without the integration of LADWP due to its geographical location within the heavily and continuously populated service area of SCE (Map 2-1). LADWP is thus functionally integrated into the CPP and participates in the hourly communication exchanges among SCE, PG&E, and SDG&E. In addition, LADWP participates in the coordinated maintenance schedules and the coordination of relay settings.[44] In terms of formal institutional arrangements, LADWP has a bilateral agreement with SCE, PG&E is connected with LADWP only through the transmission lines of SCE, but nevertheless engages in exchanges of electricity with LADWP via these connections. For example, PG&E obtained 600 MW of electricity from LADWP during the summer of 1979 in order to meet peak demand.[45] This working situation suggests that LADWP will become an official member of CPP through a reorganization of the CPPA.[46] Reorganization could occur without necessarily involving any commitment to a central dispatching office, but there is evidence to suggest that LADWP would like to negotiate for such an arrangement.

Although the preceding discussion demonstrates the existence of coordination efforts between the CPP and LADWP, Cresap, McCormick, and Paget, Inc., in their Decennial Survey of LADWP state that the cooperative effort is not significant.[47] They furthermore state that the Department has not "sufficiently taken into consideration the plans of the other major California utilities in its own resource planning efforts."[48] This implies that joint investment and planning efforts are called for. The Decennial Survey documents support the already presented argument that the employment of a centralized computer system is the only way to insure that the lowest cost combination of resources is used to generate electricity.[49] A computerized system, with its capability to rapidly handle large amounts of data, would be able to more accurately estimate actual incremental costs than is presently possible with hourly communications. By assuring that continuous adjustments were made to use the cheapest power available in the system, a centralized computer arrangement would permit the maximum efficiency to be approached.

The principal factors used by LADWP in assigning use priority to units include: fuel cost based on replacement, heat rate (incremental efficiency of the unit), maintenance cost, transmission losses, minimum loading requirements and cycling capabilities.[50] Presently, there are LADWP units, like the Castaic pumped storage facility, that are not being utilized to their fullest potential. It seems clear from the expected supply deficiencies that LADWP will face in the 1980's that it would be to their advantage to strengthen connections with the other major California utilities. A difficulty that LADWP will have to overcome in its negotiations is the perception held by PG&E and perhaps others that LADWP is difficult to work with because of the awkward situation created by its organizational structure.[51] Because decisions of the planning department and the operations office must be approved by the Board of Governors of the Department, there are inevitable delays in working with LADWP engineers. According to PG&E management, "you never get a decision until a week from Thursday," when the meetings of the Board of Governors occur.[52] It is likely that any integration agreement among other utilities will have to consider the organizational differences between LADWP and the private utilities and provide for an overruling authority which enables all of the utilities to work together in a timely fashion.

What are the views of the SEC regarding the prospects for central dispatch? In a recent report on the commercial status of electrical generation and nongeneration technologies, the SEC commented on the cost and benefits of increased power pooling in California as identified in a study contracted out to System Control, Inc. Unfortunately, neither the draft nor final version of this study could be obtained for more thorough analysis. The preliminary findings, however, indicate that more integrated power pooling would improve generation reliability and result in a reduced need for new power plants.[53] The study specifically considered: 1) the more frequent economy transactions possible under the central dispatch of generating units; 2) joint planning for generation and transmission facilities; and 3) joint maintenance scheduling.[54] According to the study, net cost savings would accrue over the cost of additional transmission and energy control facilities (even with the cost of transmission losses taken into account). Using the utility resource plans as the basis for calculations, Systems Control estimated "that central dispatch of California's major utilities by 1990, which would require an additional investment of about $600 million for transmission and control center facilities, would yield about $300 million annual savings in production costs."[55] In addition, the SEC has sponsored its own in-house project on pooling which further substantiates this view.[56] On the basis of this evidence, the SEC apparently favors the implementation of more strongly coordinated power pools in California. In fact, they point to PJM and NEPEX as evidence for the feasibility of instituting such a pool in the state.[57]

Several difficulties in establishing a central dispatch power pool need to be overcome. The perception of LADWP as a municipal utility with a different organizational structure from that of the private utilities has already been mentioned. The position of PG&E clearly demonstrates their resistance to the idea of central dispatch and the other members of CPP likewise do not see the need to take steps. Pooling legislation which was introduced in the past two sessions of the California legislature was defeated with the utilities arguing that the CPPA was sufficient and that the Federal Energy Regulatory Commission (FERC) had preemptive authority regarding the regulation of power pooling in individual states.[58] Utility resistance is thus a major obstacle to the planning of increased integration. Even if such resistance is ever surmounted, implementation will be delayed considerably by the time required both to complete negotiation of agreements and to receive the approval of the pertinent regulatory agencies, such as FERC. The few integration cost studies that have been carried out to date are meager and hardly constitute a solid base for drawing up a contract. More detailed and thorough analysis is required before the utilities would be able to formulate an agreement which would accommodate the particular needs and concerns of the respective members.

Conclusions

The foregoing discussion suggests that there exist some forces which will deter and some which will encourage the adoption of central dispatch in California. Those elements in the decision-making environment which weigh in favor of the institution of central dispatch are, in my view, extremely likely to overcome the obstacles, although it is clear that the process of establishing the physical structures and institutional agreements will be complex. The benefits to be derived from this type of energy facility have already been enumerated, namely, increased system reliability and economic efficiency. Other, less immediately obvious factors, however, should increase the appeal of central dispatch: the severely constrained power plant siting situation in the state; the financial difficulties confronting the electrical utility industry in general; the reduction of uncertainty to be obtained from assuring a continued supply of electricity; the more likely avoidance of licensing delays; and the possibility of using integrated power pooling as a response to state and federal regulatory policies.

In Chapter One it was indicated that the spatial distribution of power plants in California was not likely to be reinforced by future siting choices. Given the fairly small number of areas where power plant siting is feasible in terms of environmental acceptability, and given the fact that the total number of options available to the utilities as a group is therefore limited, it is likely that in the future the utilities will tend to prefer joint projects. Furthermore, this development is likely to be reinforced because the type of fuels that are available are constrained (e.g., federal law now prohibits new major oil-fired power plants) and thereby likely to force plant site planning to focus on the specific fuel type under consideration.[59] That is, the tendency toward joint projects also will be affected by the type of plant under consideration. The use of geothermal resources, which are inherently site-specific, does not encourage joint ownership, whereas the use of coal or synthetic fuel does. In short, the relative scarcity of possible power plant locations forces a more careful use of available sites.

Financial difficulties of the utilities are partly due to general economic conditions, primarily the rate of inflation, and partly due to the specific problems that the individual utilities have in managing their fiscal resources. Within the state there is variation among the utilities in this respect. SDG&E has more serious financial difficulties than the other investor-owned utilities and in accord with the requirements of the California Public Utilities Commission, operates under a different rate structure.[60] Because the ability of the utilities to raise capital for energy facilities has been hampered by the present situation in the economy, it has become more desirable to share the investment risks of the large-scale long-term projects required by the present technology of power plants. Since the economies of scale of the larger generating units are significant, it has become more profitable for several utilities to participate in joint projects for a specified share of a resource than to risk their capital in less efficient smaller-scale units that actually more closely approximate their capacity output needs. For some technologies, the capital investment is so great that it would not be possible for any one utility to afford the capital costs. In fact, the New England Power Pool originated as a means of drawing together sufficient capital to invest in nuclear power plants.[61] To the extent that present economic conditions will continue or worsen, then the profitability of engaging in joint projects will increase.

In California joint projects have already been undertaken as excellently illustrated by the Harry Allen coal-fired power plant proposed in Nevada. PG&E and SCE each will initially own 46 percent of the plant, with the remaining 8 percent being owned by Nevada Power and Light. Nevada Power gradually will resume a greater proportion of the ownership.[62] Other examples include the partnership of SCE and SDG&E in the San Onofre nuclear power plant and the joint ownership of the White Pine County Nevada Coal project by LADWP, other municipalities (Burbank, Glendale, Pasadena), and the state of Nevada. Moreover, the SEC has funded studies which demonstrate that the cost of building new transmission lines to permit the importation of electricity from out-of-state compares favorably with the cost of building new generating capacity in state.

We can further substantiate the trend toward increasing integration by enumerating the proposed joint transmission projects in the state. Three proposed major interstate transmission line projects are particularly worthy of mention. 1) SCE, LADWP, and various southern California utilities may upgrade an existing intertie to Oregon from the present capacity of 800 kilovolt DC to 1,000 kilovolts. This would represent an increase of 500 megawatts in capacity. 2) PG&E is considering a third 500 kilovolt AC line to connect with generating resources on the Washington-Oregon border and with a 500 kilovolt line belonging to the Bonneville Power Administration (BPA). 3) SDG&E has plans for an Eastern Interconnection Project which will connect them with the geothermal resources of the Imperial Valley and with the Arizona Public Services System via Palo Verde, Arizona.

The salient point here is that there is a documentable trend towards joint ownership of electrical generating units because of the capital investment that is necessary to actually realize such ventures. This, in turn, has created a situation which fosters more centralized generation planning and a common fuel supply program.[63] The next logical step in the development of inter-utility relationships in the state is the adoption of a central dispatch system to allocate the electricity which by ownership is already being handled in an integrated fashion. As more planned generating capacity results from coordinated efforts among the utilities, the need for central dispatch will become more imperative. The last-named factor perhaps more than anything else supports the conclusion that central dispatch is likely to appear in California in the future.

The impact of regulatory lags on licensing procedures often causes severe delays in the construction and operation of facilities. This in turn hampers utility efforts to assure a constant supply of electricity. In the short run, supply is severely limited because the lead time in construction and operation of the plants may be ten to twelve years.[64] Even after a proposed project has been underway delays are inevitable so that it is not easy to predict exactly when the plant will actually come on line. Thus, in order to assure a steady supply of electricity in the short run, available capacity must be utilized as efficiently as possible. In addition, arrangements to acquire firm contracts from outside suppliers must be made if the generating capacity owned by a given utility appears to be insufficient to meet demand forecasted over the next one to two years. As the supply becomes tighter, the greater efficiencies of operation that are possible with a central dispatch will become more important in aiding the utilities to meet their demand. Of particular interest are the steps to be taken by LADWP on the basis of the short periods of deficiency in supply they project for the 1980's. LADWP intends to improve their resource plan (a comprehensive statement of supply sources, fuel types and planned additions to capacity) by developing new projects, designing load management plans and encouraging conservation, and exploring increased integration with other utilities.[65]

Finally, the response of the utilities to the regulatory policies of the State Energy Commission further supports my conclusion that central dispatch will be adopted eventually. The utilities must convince the SEC of the validity of their demand forecasts before that agency will certify any power plant as being needed to meet projected demand (cf. Chapter Three). Clearly, it is easier to demonstrate need to the Commission if a joint project is proposed because then it can justifiably be said to satisfy a range of electrical demands within the state.[66] In addition, joint projects offer the participants the opportunity to buy in at a level that meets the specific requirements of their service areas. Again, it is to be emphasized that there is likely to be a transition in the state from a period in which conventional projects are undertaken to one in which proposed additions to capacity will be based upon the institution of central dispatch. All of the utilities stand to benefit from closer planning coordination since an integrated approach to meeting the electrical needs of the state has a greater chance of success when presented to the SEC.

FOOTNOTES, CHAPTER FOUR

1. Robert Dorfman, Prices and Markets, (Englewood Cliffs, N.J., Prentice-Hall, Inc., 1972), p. 145.

2. "Creating the Electric Age," EPRI Journal, 4 (no. 2, March 1979), p. 62.

3. Ibid., p. 82.

4. Ibid., p. 62.

5. Ibid.

6. Twentieth Century Fund, Electric Power and Government Policy, (Baltimore, Md., Lord Baltimore Press, 1948), p. 30.

7. H.H. Haup, "Power Pools and Superpools," IEEE Spectrum, 10 (no. 3, March, 1973) p.54.

8. "Creating the Electric Age," p. 62.

9. Ibid., p. 58.

10. Ibid., p. 79.

11. "Status of Power Pools, Part 1," Power Engineering, 71 (no. 5, May 1967), p. 63.

12. Capacity factor is the fraction describing the portion of total possible capacity ("nameplate rating") of a given electrical generating unit that is actually being used. For example, a 150 MW plant operating at .68 capacity factor is supplying 102 MW.

13. "Status of Power Pools, Part 1," p. 63.

14. William W. Lindsay, "Pricing Inter-System Power Transfers in the United States," New Dimensions in Public Utility Pricing:, ed. by Harry M. Trebling, (East Lansing, Michigan State University, 1976) p. 495.

15. Leonard Olmsted, "Electric Power Systems," Encyclopedia of Energy, (New York, McGraw-Hill Book Co., 1976), p. 218.

16. "Status of Power Pools, Part 2," Power Engineering, 71 (no. 6, June 1967), p. 58.

17. R.G. Rincliffe, "Planning and Operation of a Large Power Pool," IEEE Spectrum, 4 (no. 1, January 1967), p. 91.

18. Ibid.

19. *Ibid.*, p.92.

20. *Ibid.*

21. For a description of methods of computer control of electricity flow, see H.H. Haup, "Power Pools and Superpools," *IEEE Spectrum*, 10 (no. 3, March 1973), pp. 54-59.

22. Personal Interview, Elmer Kaprielian, Pacific Gas and Electric Company, San Francisco, California, November 27, 1979.

23. Rincliffe, p. 93.

24. *Ibid.*

25. *Ibid.*, p. 96.

26. H.R. Perry, "California Power Pool Description," unpublished document, Pacific Gas and Electric Company, San Francisco, California, November 1979, p. 1.

27. Kaprielian Interview. He stated that PG&E does the worrying for SMUD in the summer.

28. Perry, p. 2.

29. *Ibid.*, p. 5.

30. Kaprielian Interview.

30a. According to *Moody's Public Utility Manual* (New York, Moody's Investor Service, Inc., 1979),p.28A, PG&E is the largest in revenues and in total number of customers served:

	Revenues in millions	Number of customers
PG&E	3433.2	3,270,302
Consolidated Edison of New York, Inc.	3011.0	2,693,567
Commonwealth Edison	2442.8	2,875,453
SCE	2328.8	2,949,611
Public Service Electric & Gas (N.J.)	2219.8	1,663,762

31. Kaprielian Interview.

32. *Ibid.*

33. Albert Interview.

34. Kaprielian Interview.

35. Albert, Chouloupka, Kaprielian and Perry Interviews.

36. Kaprielian has served as the chair of the interconnection committee of the North American Power Study, and has been a member since 1965; he is personally very familiar with NEPEX and PJM.

37. Kaprielian Interview.

38. Perry, p. 8.

39. Kaprielian Interview.

40. Ibid.

41. Albert Interview.

42. Ibid.

43. Ibid.

44. Relay setting refers to the monitoring device which signals the controlling mechanism on the electrical generation equipment to vary its output in response to changes in the demand for the output.

45. Kaprielian Interview.

46. Perry Interview.

47. Cresap, McCormick and Paget, Inc., Department of Water and Power of the City of Los Angeles: Decennial Survey, (San Francisco, May 31, 1979), pp. V-19 and V-27.

48. Ibid., p. V-20.

49. Ibid., p. V-22.

50. Booz, Allen and Hamilton, Inc., Power Pool Procedures and Key Issues, (Bethesda, October 1978), pp. II-4,5.

51 Albert Interview.

52. Ibid.

53. Prabhunam Singh Khalsa and Leigh Stamets, Commercial Status: Electrical Generation and Nongeneration Technologies, Staff Draft, (Sacramento, California Energy Commission, September 1979), p. 360.

54. Ibid.

55. Ibid.

56. Personal Communication, Howard Sklar, California Energy Commission, January 31, 1980 (document unavailable).

57. Khalsa and Stamets, p. 361.

58. Ibid., p. 362.

59. California Energy Commission, 1979 Biennial Report (Sacramento, State of California, 1979), p. 43.

60. Personal Interview, Barbara Barkovich, California Public Utilities Commission, San Francisco, California, April 18, 1979.

61. Personal Interview, Edward Kahn, Lawrence Berkeley Laboratory, Berkeley, California, November 1, 1979.

62. Personal Communication, Richard Sextro, Lawrence Berkeley Laboratory, Berkeley, California, May 22, 1980.

63. Booz, Allen and Hamilton, Inc., pp. IV-4 and IV-9.

64. Cresap, McCormick and Paget, Inc., p. V-25.

65. Ibid., p. V-26.

66. Personal Communication, Roger Johnson, Los Angeles Department of Water and Power, Los Angeles, California, November 6, 1979.

CHAPTER FIVE: CONCLUSIONS

Having concluded that there is some likelihood of central dispatch developing in California, it remains to speculate on the effects of this type of utility coordination on the siting process for power plants in California. Moreover, the questions raised about the role of public facility location theory and comments on the role of the public versus private ownership debate need to be addressed. Lastly, I wish to make suggestions for further research and to comment on the process involved in completing the research for this dissertation.

Public Facility Location Theory

In the introduction, two specific questions about public facility location theory were posed. What can public facility location theory contribute to the study of the provision of electricity? What does the siting process suggest in the way of possible directions for the further development of public facility location theory? It was argued that normative theory could not play a central role in designing an approach to the problems under consideration. In addition, it was concluded that public facility location theory did not provide a useful basis for examining the problem of electrical energy facility siting since it lacks an emphasis on system interdependence and it neglects the role of other institutions in the siting process. The information presented in Chapter Four regarding the complexity of utility interrelationships further substantitates that conclusion.

In its present state, public facility location theory has additional characteristics which make it inapplicable to the electric utility problem. For one thing, the theory has been formulated at the urban scale and thus is not easily modified to deal with facility siting problems at the regional scale. Moreover, it emphasizes accessibility to the place where the service is offered while electricity is delivered to the customer. Time and distance to the service outlet are employed as surrogate measures for use while neither of these measures reflects the demand for electricity. No fee for service is assumed while electricity is directly billed. Finally, the equity and efficiency considerations prevailing for public service provision and electricity delivery are different. These differences, although important, are not the sole ground for not employing public facility location theory. The manner in which location allocation and equity and efficiency questions are handled clearly indicates that public facility location theory is confined to the consideration of siting factors. Specifically, the selection of an optimal site which minimizes costs or maximizes a measure of social welfare is arrived at by considering the spatial pattern of supply and demand. But in fact, a theory based on site accessibility criteria actually provides a siting methodology or algorithm rather than provding a model to describe or analyze the process which takes place during the siting of a power plant. Again, we face the difference between a normative approach, which is characteristic of public facility location theory and a positive approach which describes the "real world." Moreover, to merely determine if a pattern of facility locations meets equity and/or efficiency criteria ignores the evolutionary process underlying the pattern under consideration. In other words, public facility location theory could be improved if it attempted to model the underlying processes which bring about spatial patterns rather than primarily focusing on the pattern of a given moment. This is not to completely denigrate the efforts of those who analyze patterns to determine equity and efficiency implications, because their work is of some value. If one wishes to formulate a policy to ameliorate any perceived inequities in the distribution of service, it is necessary to have measures to determine both how the spatial pattern contributes to the inequities and if any improvements have indeed taken place. If the siting process is understood, then presumably future sites can be more easily selected according to the goals developed in the policy formulation.

It also is to be noted that the equity and efficiency considerations associated with electrical energy facilities include, among other things, the social costs of environmental pollution, the social problems associated with boomtown energy developments, and the impact of electricity costs on different social groups. The inherent characteristics of these social welfare questions call for a very different approach than that presently used in public facility location theory.

The work of Julian Wolpert and his colleagues on the implementation of controversial facilities and the equity and efficiency considerations thereof deserves mention in this context.[1] His approach is a step in the right direction, but it falls short because it deals with unique controversial facilities (like the construction of a bridge over the Mississippi River) at the urban scale. His work dealing with systems of noxious or controversial facilities (e.g., satellite mental health facilities) involves welfare considerations of a very different nature whose impacts are localized and not regional.

To summarize, a theory dealing with the siting of electrical energy facilities ought first to be formulated at the regional scale. Secondly,a feedback approach should be employed so as to capture the systemic nature of utility interdependence. In particular, the locational interdependence among utilities that arises from the already established infrastructure should be explicitly considered. Thirdly, measures need to be developed to deal with the special welfare considerations associated with utilities and the tradeoffs they entail. Fourthly, the role played by related institutions in the locational decision-making process must be recognized. Finally, rather than assume that it is reasonable to ignore differences in ownership by classifying all electrical utilities as public, some distinction must be made between private and public electrical utilities. Such a distinction would allow for a more sophisticated theoretical formulation because characteristic differences in decision-making behavior could be incorporated.

Public Versus Private Ownership of Electrical Utilities

In Chapter Two, the classification of investor-owned electrical utilities as private was deemed misleading to the extent that they provide a public service and hence could be classified as public facilities. Designation of the utilities as public permitted an evaluation of the applicability of public facility location theory to the siting of electrical energy facilities. It did, however, obscure identification of the ways in which the differences between public and private electrical utilities affect the siting process. In this connection, it is important to distinguish between the siting process for power plants per se and the siting process for facilities associated with a central dispatch system.

In the siting process for power plants, any joint ownership of a project necessitates the coordination of the participating utilities both in preparing the documents to be filed with the SEC and in carrying out the preparatory research on which site selection is itself based. The ways in which the difference between public and private electrical utilities affects the siting of facilities can be described in time-geographic terms which simultaneously consider the spatial and temporal aspects of locational interdependence. By definition the activity bundles[2] which must take place to complete the project[3] or siting a jointly-owned facility will necessarily require linkages between various members of the utilities whose organizational roles make them the responsible actors. The salient point here is that the coupling constraints[4] and the authority constraints[5] hindering the formation of bundles will be different in privately and publicly owned electrical utilities. Some of these constraints have already been alluded to in Chapter Five where we noted the time delays involved in LADWP's decision-making due to its being constrained by the schedule of the Board of Commissioners. The division of authority associated with the interal organization of private and public utilities would necessarily shape the ways in which they handle their coordination activities. The internal organization structure of PG&E has been described by Roberts as one strongly controlled by top management.[6] The top management participates in promotion decisions, siting decisions and other corporate matters fairly far down in the company structure. As a case in point, on one occasion higher executives disregarded the advice of those lower in the hierarchy regarding the site selection for a nuclear power plant on the coast north of San Francisco.[7] This authority was exercised even though the first such siting attempt on the coast had failed. The strong control of PG&E contrasts with the relatively weak organizational structure of LADWP. Roberts cites the diversity of professional decisions reached by the same LADWP staff as evidence of a less well defined organizational strategy.[8] Clearly this suggests that there would be conflicts in arranging coordinating activities between these utilities, for the projects and thereby the daily paths of the decision-makers are constrained in very different ways. Finally, it must be reiterated that the willingness of the utilities to <u>give up</u> their respective autonomy in order to participate in a centrally dispatched system is affected by their respective internal organizational structures.

Although the formal requirements of the Notice of Intention and Application for Certification processes are the same for both private and public electrical utilities, the attitude and experience of the utilities regarding this process does in fact vary with ownership type. First, the private utilities, if PG&E is at all representative, have more of an adversary relationship with the SEC. They view the SEC as another regulatory obstacle interfering with their freedom to choose both how to supply electricity and how to promote the use of electricity. The attitude of PG&E is shaped in part by their previous experiences with another regulatory agency, namely, the California Public Utilities Commission (CPUC).

PG&E and other private sector utilities have been under the regulatory jurisdiction of the CPUC since the Public Utilities Act of 1911 enlarged the responsibilities of the State Railroad Commission to include the establishment of rate structures for electric utilities (effective March 23, 1912).[9] Over the intervening decades the regulatory jurisdiction of the Commission expanded to include issuing "certificates of need" which approved the siting of new generating facilities. Given this long history of regulation, it is not surprising that roles have been established within the organizational structure of PG&E to deal with the CPUC, (e.g., vice president of governmental relations [Figure 5-1]).[10] Past experience has undoubtedly shaped the manner in which PG&E had handled the SEC since its inception as the primary siting regulatory agency. However, PG&E's familiarity and established ties have certainly eased their relationship with the CPUC. The amount of work required respectively in siting matters by the CPUC and SEC also heightens the contrast between them. Under the CPUC, PG&E did not seriously have to consider alternative sites in their power plant planning, even with the passage of the California Environmental Quality Act of 1970 (CEQA). Hence, some of the antagonism directed against the SEC stems from more stringent rules and the definite increase in costly preparation research required by the consideration of alternative sites. In addition, the SEC has political overtones of liberalism due to the governorship of Edmund G. Brown, Jr., the "unorthodox" nature of his appointments to the Commission (for example, the appointment of Richard A. Schweigert (Rusty), a former U.S. astronaut) and the youthfulness of many of the SEC's employees. This liberal image often proves irritating to the generally conservative management of PG&E. For instance, a PG&E representative has depicted the SEC staff as "wet behind the ear college kids."[11]

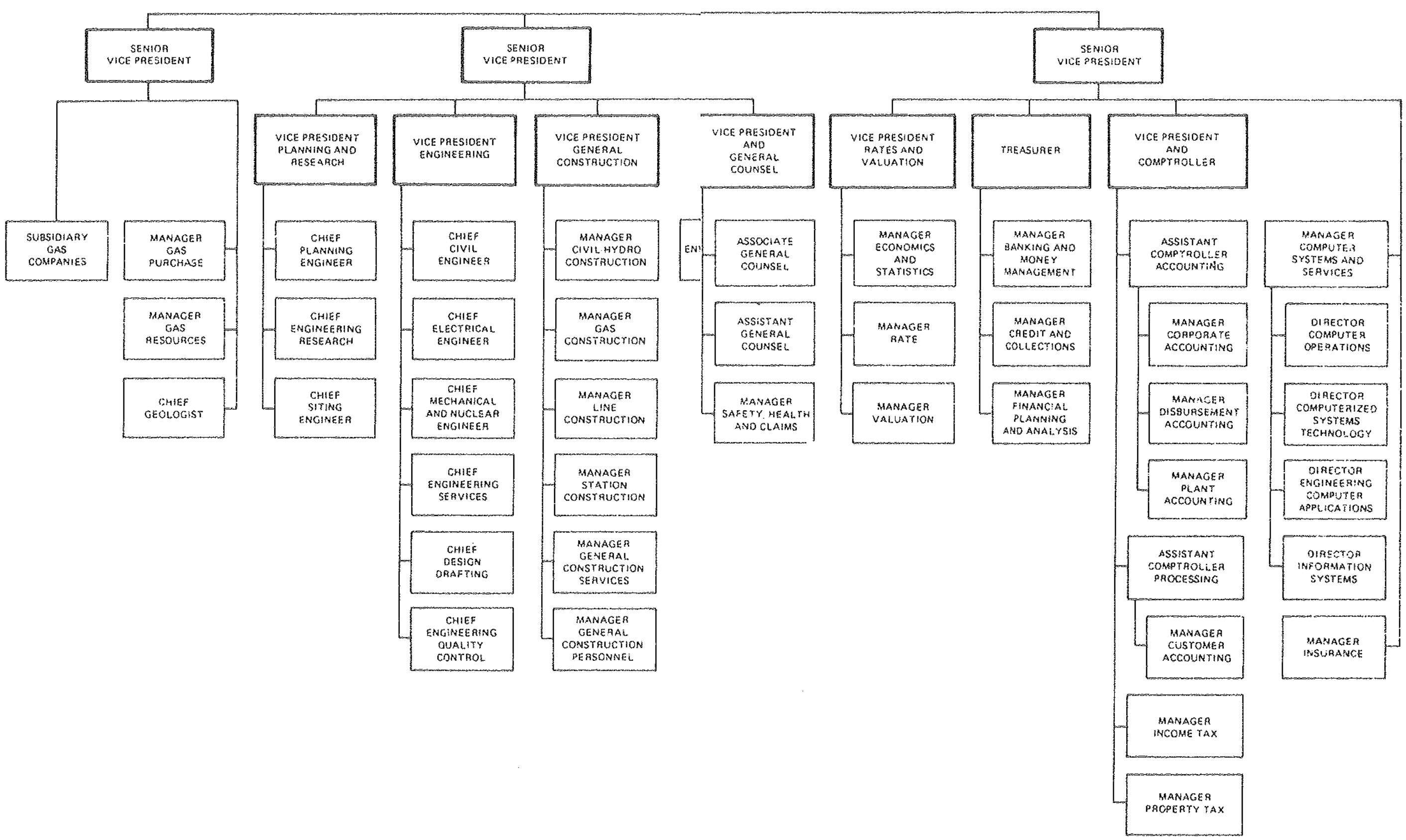
The specter of regulation by the SEC created rather different difficulties for the public utilities. The municipal utilities have not been under the rate determination jurisdiction of the CPUC. Nor have they found it necessary to go to the CPUC in order to obtain

Figure 5-1

Figure 5 1

PACIFIC GAS AND ELECTRIC COMPANY

ORGANIZATION CHART



permission to build new power plants. These matters have been governed for LADWP by the Board of Commissioners and the Los Angeles City Council. Therefore, LADWP does not seem to have an antagonistic attitude toward state-level regulatory agencies. Moreover, LADWP representatives feel the primary role of their electric utility is to satisfy the needs of the population at the lowest possible cost.[12] Such an objective would suggest that LADWP does not feel interferred with by the SEC. However, since they have not dealt with such an agency before, LADWP management feels less experienced than their private utility counterparts in dealing with the CPUC. As one LADWP representative views matters, "Getting it together" to deal with the SEC has gone slowly.[13] It should be noted that all regulatory matters are handled primarily through the two people who constitute LADWP's Office of Regulatory Affairs. Finally, due to the continuing control of the Board of Commissioners, LADWP is subject to the influence of local politics and the department perforce is quite sensitive to them. This circumstance seems to overshadow any concerns LADWP may have in dealing with the SEC.[14]

Effects of System Interdependence on Electric Utility Siting

In the final portion of Chapter Four, it was conjectured that the establishments of central dispatched electricity in California will eventually occur because the positive arguments will become sufficiently persuasive to encourage the utilities to overcome the obstacles presently standing in the way of such increased integration. It seems clear that the trend toward the undertaking of joint projects for additions to both generation and transmission capacity will continue. It seems, moreover, that this cooperation will in turn encourage even more jointly undertaken planning of future sites. Initially, efforts must be made to establish a working situation in which the planners and engineers rearrange their time to enable such joint work to be accomplished. Once their schedules have accommodated this coordinated work, however, it is reasonable to expect that subsequent projects can be carried out more readily and more smoothly. This general statement needs to be substantiated with evidence as to the patterns of behavior in such organizations.

One counter-argument can be proffered here. It is possible that some early joint projects will prove unsatisfactory to key controlling members of the utility management, thereby leading them to shun additional joint efforts. I do think, however, that the general pressures of the decision-making environment suggest that increased coordination will continue and expand. The siting process within individual utilities is likely to change in that more information will be exchanged with collaborating utilities. In particular, such collaboration will be apt to center on legal matters for dealing with the SEC. It has been suggested, in fact, that if one were seeking evidence of increased utility interaction, that the first place to look would be the development of their joint legal proceedings against the regulatory agencies, rather than the emerging effects of interactions on siting.[15] Even the LADWP representative feels the problems which arise in dealing with the SEC and the interpretation of its regulations are best handled through joint action.[16] If nothing else, it is helpful for the utilities to present a unified front to the SEC and this again suggests that dealing with SEC has encouraged the utilities to be more cooperative. For example, a PG&E representative stated: "We get our stories straight" before approaching the Commission.[17] All the same, it is important not to overemphasize the degree to which the utilities have coordinated among themselves in response to being regulated by the SEC because this is difficult to actually measure. Thus, the siting planners at PG&E have stated that the utilities deal with the Commission on a utility-by-utility basis and not as a group.[18] Yet, when the siting regulations first came out, there was a hasty ad hoc group formed among the siting planners of the major utilities in order to analyze these regulations.

Although the siting process for power plants will undoubtedly be affected by any changes in the degree of coordination, there are two reasons why it may not be possible to discern a consequent shift in the spatial distribution of electrical energy facilities. First, the siting of new power plants is so constrained by environmental and political problems that the "bank" of acceptable sites is finite and small. Thus, regardless of partnerships and joint ventures, the same sites are likely to be utilized despite the trend toward interconnections. Second, the physical pattern of the transmission lines is so interwoven with previous decisions that even if additions to transmission capacity are jointly planned, they will most likely reinforce the existing patterns. This is a reflection of the technological aspects of transmission as well as of economic considerations. It is simply too expensive to depart radically from the established transmission grid (cf. Map 1-3). Moreover, such a departure would be environmentally unacceptable on aesthetic grounds alone.[19] This does not, however, mean that geographic changes will not take place, for indeed, the activities which the utilities and the regulatory commissions engage in will be different. The composition of the jobs of individual planners will be different and consequently the projects and daily paths of the participating individuals will be altered to accommodate the changes. In addition, new roles will be created (e.g., "member of integration committee") and other roles may disappear. The use of time-geography to actually trace these effects would permit a concrete demonstration of how increased coordination activity among the utilities actually changes the manner in which they proceed with their decision-making process for power plant and transmission siting. Unfortunately, time constraints made it impossible for such a substantial documentation of anticipated effects to be undertaken in this research project.

Suggestions for Further Research

In studying the complex problem of the role of regulation and system interdependence in electrical energy facility siting in California, it has been necessary to disregard many factors which indeed are critical to a full understanding of the problem. Therefore, there are many suggestions for further research which come to mind.

One area worthy of further research centers on the impact of regulation on interstate electricity sales transfers and system interdependence. The dissertation problem treated here was restricted to regulation and system interdependence within the state of California. Hence, important broader regional and national scale questions remain. What is the role of the federal government in encouraging increased integration into the nationwide electrical grid? How has the National Energy Act and President Carter's emphasis on the use of coal and his energy policies in general affected local choices as to fuel type and technology? (Fuel type and technology are crucial factors in the selection of power plant sites.) How have the state regulatory politics of neighboring states (especially Washington, Nevada and Arizona) affected the siting process for electrical facilities? The latter is an important question because the role of interstate transfers in California's electricity supply is significant (10 percent of our electricity supply is coal-generated capacity in Arizona) and is likely to expand as future proposed plants include sites in Nevada as well as Arizona. Furthermore, the Bonneville Power Administration (BPA) plays an important role in California electricity supply because of standing contracts with PG&E for hydro capacity as well as emergency services. (These emergency services were crucial in managing the electrical supply in California during the drought). SCE also has important contracts with BPA and the construction of the Pacific Interties demonstrates the continuing interweaving of the electricity supply of the Pacific Northwest with that of California. Some consideration of these significant sources of electricity and the regional issues (such as the allocation of scarce water supplies) which they entail, must be made, because ultimately they are likely to affect siting within California.

Another important area of possible investigation is that of electricity rate structures and pricing policies. There is an extensive recent literature on pricing policies which indicates their important ramifications for the siting of both electrical generating facilities and industrial facilities.[20] Demand is the critical factor since pricing policies direct demand growth as customers respond to changes in the cost of electricity. Not only do changes in the gross amounts of electricity demanded affect the need for new power plants, but the timing of demand determines whether peaking or baseload power plants are needed. One type of pricing structure consists of so-called "declining block rates," whereby those who consume large amounts of electricity are charged less per unit of energy used than those who use smaller amounts. This structure reflects the fact that the marginal cost of providing extra units to large bulk users are lower than the marginal cost of electricity to small users. This structure yields more favorable rates for industry and "penalizes" residential users.

In California during 1975 an important rate experiment was initiated to reverse declining block rates. Several newly appointed commissioners to the California Public Utilities Commission (CPUC) instituted a new rate structure featuring "lifeline" rates for residential users.[21] Under the lifeline policy, residential users are charged lower rates if their consumption of electricity and natural gas remains below a level determined to be "necessary." This policy applied to all residential users, not only the needy or elderly segments of the population. Presently the cost of electricity and gas delivered to the residential sector is not being met by the revenues from that sector. PG&E reported to the CPUC that in 1977 residential customers paid a negative two percent rate of return.[22] In total, the lifeline has forced an annual shift in the revenue load from the residential sector to the agricultural, commercial and industrial sectors, which exceeds one-half billion dollars.[23] Symons, a commissioner of the CPUC, contends that this circumstance will encourage industries to locate in states other than California. In support of his contention, Symons cites the following three corporate representatives: Joseph Clearly of Airco, Inc.:

> At present...we do not look upon California with favor. Anything but. We would add plants here only if there were no viable option. In other words, in close competition with other states, California would lose every time. Airco has 23 power intensive plants operating across the nation. Two are in California. Over the past two years, the average power price for these 23 plants has increased by about 12 percent. But for the two in California, it has increased by over 150 percent.
>
> The large and disproportionate increase in California would be alarming enough if it were cost related. But it is not. Instead it results substantially from the CPUC's abandonment of cost-of-service principles.[24]

Gerald Fuller of Owens-Corning Fiberglass Corporation:

> ...recent actions by a state regulatory body—the public utilities commission—...are contrary to recent progress in encouraging business growth in California.
>
> ...the PUC policy will place some industries at a competitive disadvantage...(T)hey will pay penalty rates and be put at an economic disadvantage to competitors in other nearby states. Such conditions will force companies with expansion plans, such as ourselves, to look elsewhere than California for competitive plant sites.[25]

R.R. Imsande of Anheuser-Busch, Inc.:

> To indicate the magnitude of the problem in California, I would like to refer to the following few statistics. For example, electricity supplied by PG&E to our Fairfield Brewery costs us 3.6 cents per kilowatt-hour. Electricity supplied to our Merrimack Brewery by Public Service Company of New Hampshire costs us 2.7 cents per kilowatt-hour. Electricity supplied by Houston Power and Light Company to our Houston Brewery costs us 2.0 cents per kilowatt-hour. Electricity supplied by Union Electric Company to our St. Louis Brewery costs us 2.2 cents per kilowatt-hour.
>
> On a total dollar basis, we paid of $2,175,000 in 1977 for electricity at our Fairfield Brewery. If we were billed at the Houston rate, our electric cost would have been $1 million less in 1977.[26]

A PG&E representative has also noted that Governor Brown claims to woo industry but in fact is "squeezing" it out of the state. These positions suggest that the rate structure for electric energy (as well as natural gas) is a significant factor in industrial corporate location decision-making and worthy of research.

A final area for possible further research centers on the impact new energy sources will have on the types of plants developed and the sites chosen for them. The present analysis did not concern itself with the influence fuel source characteristics have upon the power plant locations selected by electrical utilities. Presently, conventional fuels (hydroelectricity, oil, gas, coal and nuclear) are used in California and the utilities are still geared toward a conventional energy path.[27] However, that situation is obviously subject to change. A PG&E representative stated that he is "not looking for sites" for centralized solar thermal electricity generating plants because solar thermal does not appear commercially available within the company's planning horizon.[28] It is debatable, however, as to whether or not this statement is realistic, especially considering the proposed demonstration project for a 10 MW pilot plant outside Barstow, California. Nevertheless, the attitude of PG&E reflects the present bias of the utilities in favor of conventional energy sources.

Despite the policies of the SEC aimed at encouraging the adoption of nonconventional energy sources, it is clear that the distinctive problems associated with such sources will affect regulatory issues and system interdependence in the near future.[29] In particular, solar energy presents some interesting problems. For example, if people begin to rely primarily on solar energy to meet their hot water requirements and install electrical backup systems, how should the utilities deal with the problem of intermittent but short duration sharp increases in the demand for electricity? (Such increases could occur during those brief periods of bad weather when the use of electrical backup systems becomes necessary.)[30] The capital investment needed for generation equipment to meet such demand would be substantial and would not be used efficiently. Centralized solar thermal generation likewise raises questions of system reliability and interdependence. The integration of relatively small decentralized sources of electricity into the present system requires the resolution of both techical problems involving cogeneration and generation through pyrolysis of solid waste, for instance, and institutional problems arising from increased competition. If sufficiently large in number, such small projects would result in a shift from a centralized pattern of electrical generating facilities to a decentralized pattern.

Finally, conservation can be thought of as a nongeneration technology which is a "new source" of energy for meeting the electrical demand of the state. Like other new sources, it poses significant research questions that are likely to be singled out for investigation as the limitations of conventional energy paths become more obvious and more serious.

The Process of Doctoral Research

The inherent problems in carrying out doctoral dissertation research gradually became clear to me over my years of working. The transition from my original idealistic aspirations to a more pragmatic view was painful and disillusioning. That this research is incomplete and limited in its contributions may be of no surprise to those who have undertaken such work themselves. It has not been possible for this dissertation, which was completed under time and resource constraints, to attain the quality and scope I had originally envisioned.[31] I am determined, however, to do more work in the areas which require attention. I recall a statement contained in a paper of mine from March 1978:

> While my dissertation must constitute an original piece of research regardless of the topic, if it is in an area where few have entered then I feel more confident that it will be of greater importance and value academically. In this I am drawing the distinction between disseration research that is primarily derivative (such as dissertations on factorial ecologies of cities) yet of sufficient originality to be considered acceptable for the doctoral research and dissertation research that is more creative. The intellectual community around me has convinced me to strive for as much creativity and originality in my work as possible. I cannot say at this point that I will undoubtedly be able to accomplish this but I do not wish to content myself with a dissertation that does not aspire to higher goals.

As a consequence of my desire to strive for creativity, I undertook a "messy" and extremely complicated problem which had no clear methodological approach. Perforce, I have not been able to solve the complex web of circumstances involving regulation and system interdependence in siting. (There have been innumerable occasions when I had heartfeltly wished that I had obliviously chosen a nice concrete null hypothesis, developed a statistical measure, blithely collected information, performed the calculations and been able to accept or reject my hypothesis. If it were derivative the literature review would have been easier as well.) The one overwhelming realization is that complexity on many levels is the only consistent feature of this dissertation problem. So many factors have a bearing on the problems addressed that at times it has seemed hopeless to attempt to make any sense of them. Despite any disillusionment, I feel that I have intellectually developed while preparing the dissertation and in the course of doing so I have grappled with the basic philosophical issues that are essential to organizing quality research. The unfortunate aspect of the final product is that it is impossible for it to reflect the intellectual process I have gone through. Now I regard the word "partial" on the title page in a special light.

FOOTNOTES, CHAPTER FIVE

1. Anthony J. Mumphrey and Julian Wolpert, "Equity Considerations and Concessions in the Siting of Public Facilities," Economic Geography, 49 (no. 2, April, 1973), pp. 109-21.

2. The gathering of two or more individuals and/or objects at a physically fixed location for production, consumption, social and miscellaneous activities is referred to as an "activity bundle."

3. "Project" refers to the steps, people and materials necessary to accomplish specific production, consumption and social goals. For example, the project of giving a birthday party can be broken down into the steps of shopping, food preparation, et cetera which result in bringing together the resources and people that constitute the party.

4. "Coupling constraints" denote where, when and for how long an individual must join other individuals or objects to form activity bundles.

5. "Authority constraints" consist of the general laws, economic barriers and power relationships that determine which individuals have access to particular activities at particular times.

6. Marc J. Roberts, "An Evolutionary and Institutional View of the Behavior of Public and Private Companies," American Economic Review, 65 (no. 2, May 1975).

7. Ibid.

8. Ibid., p. 420-421.

9. Charles M. Coleman, PG&E of California: The Centennial Story of the Pacific Gas and Electric Company 1852-1952, (New York, McGraw Hill Book Co., Inc., 1952), p. 249.

10. Personal Interview, Betsey Krieg, Pacific Gas and Electric Company, San Francisco, California, November 27, 1979.

11. Personal Interview, Edward Chouloupka and Richard Albert, Pacific Gas and Electric Company, San Francisco, California, November 13, 1979. Chouloupka mentioned that they gave the SEC all the data that they requested but that they did not think it would be possible for the SEC to assimilate all of it given their staff capabilities. Chouloupka and Albert found it ironic that the sheer weight of all the heavy seven-inch thick files caused the floor of the storage area to collapse. It contributed to their feeling that the SEC did not know what they were doing.

12. Personal Communication, Roger Johnson, Los Angeles Department of Water and Power, Los Angeles, California, November 6, 1979.

13. *Ibid.*

14. *Ibid.*

15. Personal Interview, Edward Kahn, Lawrence Berkeley Laboratory, Berkeley, California, November 1, 1979.

16. Johnson Interview.

17. Chouloupka Interview.

18. Albert Interview.

19. Personal Interview, H.R. Perry, Pacific Gas and Electric Company, San Francisco, California, November 27, 1979.

20. See for example: Elizabeth E. Bailey and Eric B. Lindenberg, "Peak Load Pricing Principles: Past and Present," *New Dimensions in Public Utility Pricing*, ed. by Harry M. Trebling, (East Lansing, Michigan State University, MSU Public Utilities Studies 1976), pp. 9-36. California Energy Resources Conservation and Development Commission, *Electricity Pricing Policies for California*, (Sacramento, CERCDC, May 1977). California Public Utilities Commission, Utilities Division,Electric Branch, *Staff Report on Electric Utility Rate Structures*, (San Francisco, CPUC, March 1975). W.W. Carpenter, "Marginal Cost: A Critique of Its Progress," *ELectrical World*, 189 (no. 7, April 1, 1978), pp. 36-58. W. Donald Crawford, "An Electric Utility Perspective on Rate Design Revisions," *Public Utilities Fortnightly*, 102 (no. 6, September 13, 1978), pp. 15-17. Federal Energy Administration, Offices of Energy Conservation and Environment and Energy Resource Development, *Electric Utility Rate Design Proposals, Interim Report* (Washington, D.C., U.S. G.P.O., February 1977). ICF,Inc., *Technical Institutional and Economic Analysis of Alternative Electric Rate Designs and Related Regulatory Issues in Support of DOE Utility Conservation Programs and Policy*, (Washington, D.C., ICF, Inc., May 1979). William W. Lindsay, "Pricing Intersystem Power Transfers in the United States," *New Dimensions in Public Utility Pricing*, ed. by Harry M. Trebling, (Eash Lansing, Michigan State University, MSU Public Utilities Studies, 1976), pp. 493-512. Patrick C. Mann, "Rate Structure Alternatives for Electricity," *Public Utilities Fortnightly*, 99 (no. 2, January 20, 1977), pp. 28-34. Daniel McFadden, *Forecasting the Impacts of Alternative Electricity Rate Structures: A Feasibility Study, Final Report*, (Berkeley, University of California, Department of Economics, December 1976). John Schaefer, "Marginal Cost: How Do Methods Compare?" *Electrical World*, 191 (no. 4, February 15, 1979), pp. 84-86. William G. Shepherd, "Price Structure, Social Efficiency, and Equity," *New Dimensions in Public Utility Pricing*, ed. by Harry M. Trebling, (East Lansing, Michigan State University, MSU Public Utilities Studies, 1976), pp. 125-143. Ralph Turvey and Dennis Anderson, *Electricity Economics: Essays and Case Studies*, (Baltimore, Johns Hopkins University Press, 1977).

21. Albin J. Dahl, "California's Lifeline Policy," Public Utilities Fortnightly, 102 (no. 13, August 31, 1978), pp. 13-22.

22. William Symons, Jr., "California Rate Experiments: Lifeline or Leadweight?" Public Utilities Fortnightly, 102 (no. 9, October 26, 1978), p. 12.

23. Ibid.

24. Ibid., p. 13.

25. Ibid., pp. 13-14.

26. Ibid., p. 14.

27. California State Energy Commission, Preliminary Action Agenda, (Sacramento, CSEC, 1979), p. viii.

28. Chouloupka and Albert Interview.

29. Preliminary Action Agenda, pp. ix-xix.

30. Personal Communications, Peter Benenson and Edward Kahn, Lawrence Berkeley Laboratory, Berkeley, California, November 14 and 15, 1979, respectively.

31. Aaron: "So you must resolve
That what you cannot as you would achieve,
You must perforce accomplish as you may."

Titus Andronicus (II, 1:104) by William Shakespeare.

APPENDIX I

INTERVIEW PROCESS

The design of the research precluded interviewing a randomly selected population of people Instead, selection of members of the Pacific Gas and Electric Company (PG&E) was based on the role of the person in the scheme of the decision-making process (for example, the chief manager of power control operations was interviewed),[1] and perforce by those who would consent to be interviewed. Established personal contact between the Lawrence Berkeley Laboratory and PG&E made a critical difference in "legitimizing" my request of interview time. The interviews, conducted in person at the PG&E office in San Francisco, lasted approximately two (2) hours each, a generous amount of interview time. Because of the defensive posture of those interviewed, I judged it to be detrimental to attempt to tape record the sessions (although I went prepared to do so) and so only notes were taken. In addition, the format was flexible so each person was not asked the same set of questions. I began with an introduction of myself, and of geography, (location theory in particular) and my desire to determine how the interconnections among California utilities affect the decision-making process for siting power plants. I discussed my intended use of the interview data. Thus, if the interviewees desired anonymity or had any concerns about the manner in which the research was being conducted they could feel free to deal with these issues before answering specific questions (Table I-1).

It is essential to realize the intrinsic difficulty of interviewing utility and regulatory agency representatives about the effects of

Table I-1

Questions Used in Interviews of PG&E Staff

1) How would you define system reliability?

2) How can system reliability be improved?

3) Is there a possibility of a central dispatch system in the state?

4) Has the way system reliability affects siting been changing?

5) What factors contribute to system interdependence?

6) Is the question of private versus public ownership of utilities pertinent to the siting process?

7) How has the institution of the state energy commission changed: a) how you do your work, and b) your relationship with other utilities?

8) How does the present regulatory situation compare with being primarily under the jurisdiction of the Public Utilities Commission?

9) What role does the demand forecast play in your siting work?

10) How did the drought affect the coordination among the utilities?

11) Do you have a working relationship with analogous people in other utilities?

12) What organizations play an important role in coordinating your work with other utilities?

13) What is your educational background? History with PG&E? What roles have you held and what types of projects have you worked on?

system interdependence on siting. First, the interviewees at PG&E, LADWP, SEC or CPUC were unaware of geography as an academic discipline in which advanced degrees are available. Secondly, since the interviewees did not understand what geographers do, this severely hampered their general ability to respond to my inquiries. Given their training in electrical engineering, mechanical engineering, nuclear physics, et cetera, there was no reason to expect them, with only a brief description of geography and my dissertation project, to be able to make the kinds of connections about their work that I suspected were there. My desire to obtain an overview of broad trends in siting seemed in some way alien to those interviewed. This was because they deal with siting and coordination in a piecemeal fashion, and because they have not thought out the relationships existing between their day-to-day work and that of other utilities, regulatory agencies or even other departments within their own organization.[2] For example, the PG&E siting planners perceive physical interconnections or transmission network interties as "the relevant" aspect of utility siting; but they do not consider regulatory factors and other complications.[3]

If more time had been available for those interviewed to ponder my ideas and questions, the results of the interviews might have been different, perhaps affording more concrete and specific information for me to use in evaluating likely siting effects. An SEC representative declared within three minutes of conversation that there are presently no strong interactions between power pooling and siting and that he suspected there would be none in the future.[4] This was discouraging because it seems obvious that he could not have reflected on the possibility of there being a connection. Furthermore, his statement does not negate the possibility of there being a connection. Once again, the main point is that one of the most severe limitations in attempting to gather information by interviewing utility representatives is the difference between the mental constructs of those people and my own as a geographer. It is also disspiriting to further speculate on other factors that undoubtedly affected the interview process, such as my being young, a student and a woman.

Matters were further complicated by the fact that PG&E is presently under a great deal of public pressure as a result of the controversy over both the Diablo Canyon nuclear power plant and proposed and granted increased rates. Its executives are acutely aware of the company's negative public image.[5] A clear consequence of this was a hesistancy on their part to be interviewed and a defensiveness which called for careful interpretation of the materials gathered in the interviews. How much of what was said was propaganda? How much was company policy statement as opposed to each person's view of a given matter? Is it possible to determine if they described how things are supposed to happen or how they actually happen? In the end, it was my subjective interpretation of the interview materials that provided tentative answers to these extremely important research questions. At one and the same time, my interpretations are both defenseless and defensible. They are defenseless because someone who knows more about different aspects of the problem or has had access to proprietary information or other knowledge might be able to criticize my arguments or discern deficiencies in my presentation. They are defensible because given the information available to me, I exercised careful discrimination and interpretation.

FOOTNOTES, APPENDIX I

1. Four people were interviewed: Richard Albert, Edward Chouloupka, Elmer Kaprielian, and H.R. Perry, Pacific Gas and Electric Company, San Francisco, California, November 1979.

2. Personal Interview, Edward Chouloupka, Pacific Gas and Electric Company, San Francisco, California, November 13, 1979.

3. Ibid.

4. Personal Communication, Howard Sklar, California State Energy Commission, Sacramento, California, January 31, 1980.

5. Albert, Chouloupka and Kaprielian Interviews, November 1979.

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